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JOURNAL OF ANATOMY AND  
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# JOURNAL OF ANATOMY AND PHYSIOLOGY

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# JOURNAL OF ANATOMY AND PHYSIOLOGY

THE MORPHOLOGY AND HISTOLOGY OF A HUMAN EMBRYO  
OF 8.5 MM. By H. L. BARNIVILLE, B.A., M.B., *Demonstrator of  
Anatomy in University College (N.U.I.), Dublin.*

## INTRODUCTION.

THE embryo which is the subject of the following investigation was obtained in January 1913 in the Frauenklinik at Giessen (director, Professor Opitz) by operation on a woman in whose case an excision of the uterus was rendered necessary on account of tuberculosis, and came into the hands of Professor Keibel through the kindness of Dr Jaschke. It is now included in the Keibel series as No. 1495 at the Anatomical Institute of the University of Freiburg in Breisgau. The embryo came into the fixing fluid in an exceedingly fresh condition, and, when a series had been made, proved to be in such an excellent state of preservation that I undertook, at Professor Keibel's suggestion, a description of the whole anatomy, with the intention of making it as complete as possible as far as the more interesting points were concerned. Accounts of the morphology of individual embryos have been frequent in the literature since the time of His: and although a certain amount of overlapping must obviously occur in the observations of various authors, the value of such work is none the less very appreciable. An accurate idea of a given stage in the development of an organ or part cannot be scientifically founded on a single description; and just as our knowledge of adult morphology has been built up by the combination of often very divergent interpretations of a given condition, in the same way must our data, with regard to the course of embryological evolution, be raised to a higher plane of scientific accuracy by the elimination of the personal factor in the equation.

Of recent years two papers have appeared which have a special bearing on the present research—that of Ingalls on a 4.9-mm. and that of Elze on a 7-mm. embryo; and any subsequent worker along the same lines must necessarily feel himself more especially indebted to these two exhaustive

references, providing as they do not only many valuable suggestions but also a definite guide in the treatment of an otherwise somewhat diffuse subject.

The methods employed were those already described in the literature and applicable in a work of the kind. The embryo was fixed in a sublimat-pieric acid fluid, and after being photographed (Plate I. fig. 1) was embedded in celloidin-paraffin. The block was provided with guiding lines after the glass-box method of Born and Peter, cut in series with a sectional thickness of  $10\mu$  and stained with eosin-azure. The resulting sections are of excellent quality, and provide a well-nigh perfect histological picture, with numerous mitotic figures and a normal condition in the contour of the epithelial linings of the various organs, vessels, and body-spaces. The nerve trunks, although their constituent fibres remain unstained, are sharply defined owing to the characteristic appearance of the sheath-cells, as well as the contrast afforded with respect to the surrounding mesoderm, and can be followed to their ultimate terminations. Figs. 7 and 8 on Plate II. will provide an idea of the condition of the cellular histology under high magnification. Small but comparatively unimportant folds occur in some of the sections. The plane of section is not quite horizontal, as will be seen from the text figures, so that the left side of the latter (representing the right side of the embryo) pictures in each case a level somewhat oral in respect to the right side. Graphic profile reconstructions were made of the various systems (figs. A, B, and C), after the methods employed and described by different workers and epitomised by Peter in his *Methoden der Rekonstruktion*. The left side of the embryo was in each case taken as the basis of the reconstruction, but in at least one case a condition occurring in the right side and absent on the left was added in, viz. the connexion between N. IX. and N. X. A few reconstructions from an antero-posterior aspect were also made in the case of some of the organs, viz. the anlage of the lung, in order to obtain a more definite picture of their condition than was possible merely from a study of the sections or from a lateral reconstruction. The guiding-line system employed was two-fold, in some cases both being utilised for comparison and to eliminate errors; on other occasions one or other separately was found to be the more accurate. These were: (a) the guiding lines of the block combined with those which were subsequently drawn on the individual outlines of the sections, and (b) the outline of the whole embryo obtained by an enlargement of the photograph by means of the projection apparatus. Such reconstructions, as has often been pointed out, are not to be regarded as quite free from error even with the most accurate manipulation of the guiding lines, but the results obtained are such as cannot be so conveniently

produced by other methods, and indeed, as for instance in the case of the arterial and venous systems, are almost impossible of achievement by the wax-plate method. A comparison of the reconstructions with the text figures will further show that discrepancies are practically absent, and where such are found they will prove to be so minimal as to be negligible for all practical purposes. Wax models after the Born method were prepared of some of the individual organs, and are reproduced in the drawings on Plates I. and II. The text figures were drawn direct from the projection apparatus, and are faithful in outline and detail.

### LENGTH OF THE EMBRYO.

The embryo, measured from the photograph in which it was subjected to a definite known enlargement, has a greatest length of 8.5 mm. When embedded and cut it provided a series of 840 sections of  $10\mu$ , so that shrinkage, if any, has been very slight. According to Mall's method of reckoning, the embryo would thus have reached the early part of the thirtieth day of its development. In view, however, of the conclusive researches of Bryce, a correction must be made of the Mall formula, viz. the addition of five days to the age, which would place our embryo quite at the end of the fifth week.

### EXTERNAL BODY-FORM.

The embryo, as seen from the photograph (Plate I. fig. 1), falls between figs. 9 and 10 of the His Normaltafel and between figs. xiii. and xiv. of the Normaltafel of Keibel and Elze, resembling the former more closely than the latter. Fig. xiii. is of the embryo (7 mm. *ca.*) which has been the subject of a full description by Elze, and which will be frequently referred to in the following pages. A comparison with that figure, however, will show that the present embryo shows an advancement in many particulars. It is not so curved on itself either cranially or caudally, although the cervical bend is very sharp and approaches a right angle. On the outer surface of the head region the cerebral hemispheres, the optic cup and lens, and the roof of the fourth ventricle show up distinctly. Behind the eye and above the maxilla and mandible is the swelling of the trigeminal ganglion, and still further back above the hyoid arch is the swelling caused by the otic vesicle, with the ductus endolymphaticus continued dorsally from it lateral to the roof of the hind-brain as a very apparent streak. The nasal pit looks laterally as well as towards the heart, and the lateral and medial nasal processes being more prominent, it is deeper than in Elze's embryo. Three visceral arches are to be distinguished. The mandibular arch is subdivided by a horizontal groove into two swellings, while its maxillary process takes a



definite part in completing the margin of the nasal pit. It shows further a secondary vertical groove which runs almost parallel with the nasolacrimal groove and ends dorsally caudal to the optic anlage (see Plate I. fig. 3). This groove first appears in fig. xv. *r.* of Keibel and Elze's Normaltafel, and is seen in fig. xviii. from the same source, reproduced as fig. 49 of Keibel and Mall's *Text-book*, vol. i. The hyoid arch is also subdivided by a horizontal groove, and has an opercular prolongation continued caudally from it. The first branchial arch is sunken into the sinus cervicalis, which still possesses a wide triangular opening. The placode formations in connexion with N. IX. and N. X., or, more strictly, the openings of the ductus branchialis II. and ductus branchialis IV., can be seen on the surface anterior and posterior to the third arch respectively. In the anterior extremity an oval hand-plate and short forearm, and in the posterior an oval foot-plate are to be recognised. The axis of each limb is set at an oblique angle with respect to the dorsal line. The segmented muscle plates and sclerotomes are very obvious in the dorsal and caudal regions. The tail is spirally twisted on itself and is curved towards the left of the umbilical cord, which maintains a more or less medial position. The heart swelling does not quite reach the cord, and is more definitely marked off from the liver than in fig. xiii. above referred to. There is furthermore a slight surface demarcation between the auricular and ventricular sections of the heart in the form of a short groove or pit about midway along the groove separating the two organs.

#### NERVOUS SYSTEM.

*The Brain.*—The morphology of the brain, as seen in outline in the profile reconstruction (fig. A), shows a general similarity to that of the well-known His model of a fourth-week embryo (6.9 mm.), and that of Elze (7 mm. *ca.*). A few points may, however, be noted as marking an advancement. The anlage of the cerebral hemispheres is more pronounced, but a partial separation of the two halves is as yet indicated merely by a shallow fossa (fig. 9), at the bottom of which is a low ridge. On the floor of the diencephalon are seen the mammillary and infundibular swellings, and more anteriorly a less well-marked swelling—the torus opticus. Between the two latter is a shallow pit where the hypophyseal pocket lies against the brain-floor. On the roof of the mid-brain, in the middle line and in the position marked by an arrow (fig. A), is a small area, extending over about four sections ( $10\mu$ ), in which the structure of the brain-roof differs from the general type (fig. 1). The outer aspect of the brain-wall shows a small, nipple-like projection, corresponding with which, on the inner surface, is a shallow pit. The wall of this recess

consists of radially arranged cells, of which the nuclei, in marked contrast to the rest of the neural tube, are confined to the outer layers, leaving an inner protoplasmic layer free from nuclei. In the junctional zone between this projecting area and the normal brain-wall are numerous darkly

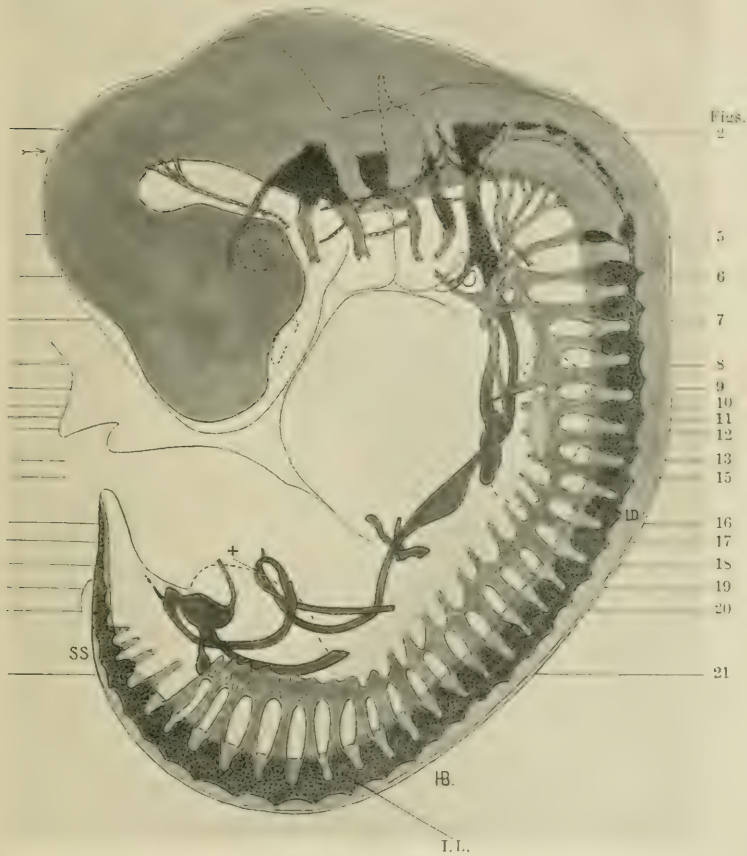


FIG. A.  $\times 12\frac{1}{2}$ .

staining nuclei. This finding corresponds exactly in its appearance with the structure described in a similar position by Elze (7 mm.), and in its histology with the description given by Mihalkovics of the histology of the early pineal outgrowth. There can be little doubt that it represents the early anlage of this structure. The isthmus is well marked. The very thin roof of the rhombencephalon has become invaginated into the ventricle



during embedding. The side wall and floor have well-marked neuromeres, though the most posterior is short and is seen only dorsally at the level of the origin of the vagus (fig. 2). The neuromeres are most marked on the inner face of the brain-wall in the form of grooves, but they involve also the mantle layer. The first has no nerve-root in connexion with it, and constitutes the cerebellar neuromere. It blends below with the second neuromere (or "first" neuromere proper, according to Streeter's reckoning). The relation of the various cranial nerves to these structures is essentially that described by Streeter, etc., for man, except in the case of N. VI., which does not arise exclusively from the fourth neuromere (*cf.* below) Early

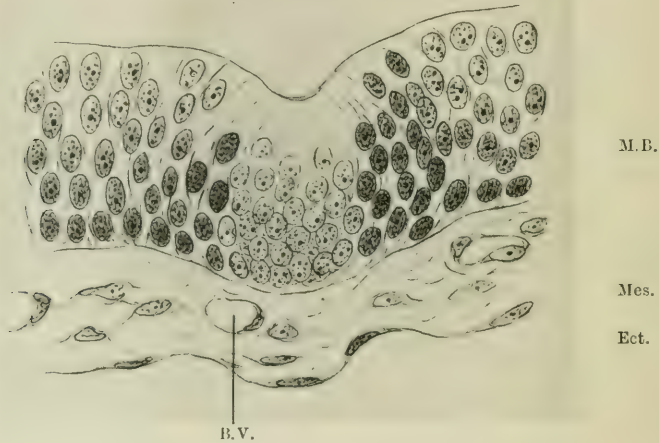


FIG. 1.  $\times 1500$  ca.

indications of some of the future tracts in the rhombencephalic wall are indicated. In the marginal zone of the floor numerous transversely coursing fibres mark the "Bodenkommissur," and on either side, near the mid-ventral line, is a group of longitudinal fibres—the future median longitudinal bundle. The entering fibres of N. V. sweep in part forwards and upwards, and although, owing to absence of staining, they cannot be traced clear of the first neuromere, may probably indicate an early tractus cerebelli V. Other fibres take a backward direction, as is the case with the cranial nerves generally, the entering fibres assuming in part a longitudinal direction in the reticular marginal zone, without forming definite tracts except perhaps in connexion with N. X. Immediately above the longitudinal fibres the marginal zone diminishes in thickness and almost disappears, exactly as is seen in the spinal cord dorsal to the posterior funiculus.

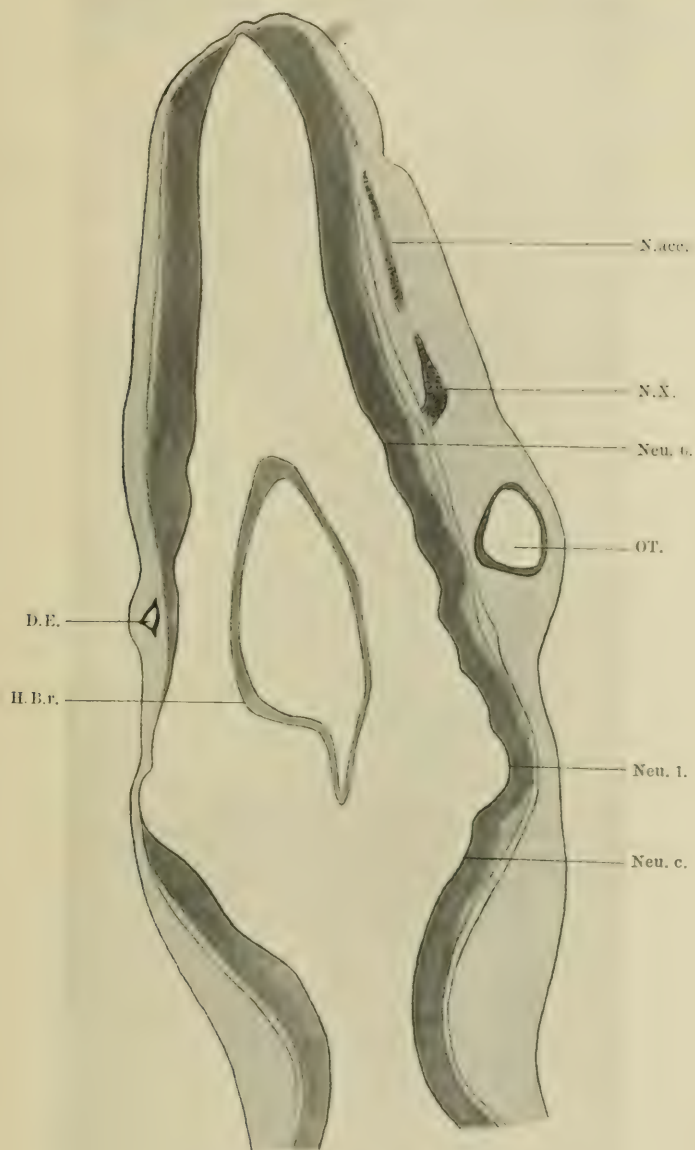


FIG 2.  $\times 30$ .

*Spinal Cord*.—The lumen of the neural tube can be followed to within four sections ( $10\mu$ ) from the caudal tip, the tube itself blending aborally with the epithelium covering the tip. The wall in this region consists of a single layer of high columnar cells, as Lenhossék describes; the only suggestion of layer-differentiation is the frequent appearance of mitotic figures in the nuclei of the innermost zone. Near its caudal termination the lumen contains two large clumps of degenerating cells attached to the roof of the tube and extending in each case through about ten sections (fig. 20). Elze (7 mm.) has described similar groups of cells lying free in

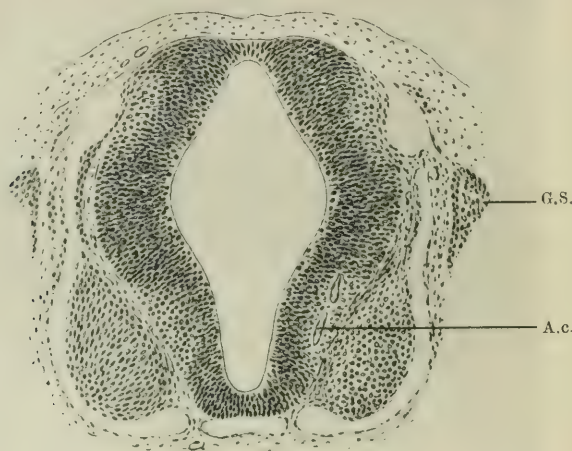


FIG. 3.

the lumen. Here can be most conveniently included a short account of the condition of differentiation of the wall of the neural tube in general. An examination, for example, of a section passing through the upper cervical region (fig. 3) shows that the wall may be divided for descriptive purposes into three main layers. This condition is best marked in the region of the anterior horn anlage. Internally is a broad layer of darkly staining nuclei and radially arranged protoplasmic filaments, the whole affording the usual radially striated picture of early stages. Its inner zone shows numerous mitotic figures (germinal layer). Outside this layer is the clump of anterior horn nuclei, less darkly staining and having no radial arrangement. Between these two is a thin layer of circumferentially arranged oval nuclei and fibres—the “zona arcuata” of His. This arcuate

zone is continued dorsally internal to the posterior longitudinal fibre-bundle around which the nuclei become more numerous, constituting an early posterior cell column (His). This zone of fibres and cells forms a markedly differentiated mantle layer, but it is not the sole expression of the process of differentiation in this layer. The outer zone of the radially striated layer shows a loosening up of its structure ("aufgelockerter Theil" of His) inasmuch as the nuclei are less radially arranged, set farther apart, and stain as a whole less deeply than in the rest of the layer. This process is scarcely noticeable in the region of the sulcus limitans, but is well seen dorso-mesial to the posterior longitudinal fibre bundle, and more particularly opposite the anterior horn anlage, the latter having the appearance of "invading" the inner layer across the barrier of the zona arcuata. This loosened zone is then discontinuous dorso-ventrally, in contrast to the arrangement figured by His, and the appearances indicate that this further differentiation of the mantle layer occurs earliest in the two above-mentioned situations. The outermost layer is quite free from nuclei, and consists of fibres running in various directions, giving it a reticular structure. It is thickened antero-mesial to the anterior horn—the funiculus anterior, and opposite the entrance of the posterior root fibres—the funiculus posterior: dorsal to this it is absent. A well-marked anterior commissure is present, and derives its fibres mainly from the zona arcuata. Some of the fibres, however, do not cross, but sweep around the mesial aspect of the funiculus anterior to remain on the same side of the cord. Traced headwards the anlage of the funiculus posterior fades away a short distance anterior to ganglion C. I. Caudally it can be traced as far as the second sacral segment, beyond which a definite anterior horn also becomes indistinguishable—although ventral root fibres arise down to the level of the first coccygeal segment. The anterior horn anlage traced orally can be followed into the rhombencephalon as a thickening of the differentiated mantle layer, from which the rootlets of N. XII. arise. The remainder of the wall of this portion of the brain consists of a radially striated layer with its inner germinal zone of mitotic figures and a loosened outer zone, and enveloped by a reticular layer containing the fibre tracts above described. The fore-brain is lined by a radially striated layer quite undifferentiated dorsally and laterally, but ventro-laterally there is a slight loosening-up process apparent in the outer zone, here covered by a thin clear layer free from nuclei.

*Cranial Nerves.*—The general arrangement of the cranial nerves, as seen in the profile reconstruction (fig. A), corresponds with Elze's (7 mm.) description, and in the case of N. IX., X., XI., and XII. with the account given by Streeter for embryos about this age.



N. III. arises by a large number of fasciculi from the floor of the mid-brain. In its course it runs internal to the "vena capitis medialis" (Grosser), and to the ophthalmic division of N. V., with which latter it is in connexion, as will be later referred to under N. V. It ends in two terminal branches in a well-defined mass of condensed mesenchyme in which N. VI. ends more posteriorly. This is the anlage of the orbital pre-muscle mass, and lies postero-dorsal to the optic cup and external to the A. carotidis interna. The nerve shows no ganglion cells along its course. Of N. IV. no part could be definitely recognised either in its intra-cerebral or peripheral course. The non-discovery of this nerve after careful searching must be ascribed to its small size, the undifferentiated condition of its nuclei, and more particularly to the fact that it would be cut transversely throughout its whole course. Elze notes only the crossing of the fibres in the roof of the brain, and fails to find any trace of its peripheral fibres.

N. V.—The central fibres of the trigeminal ganglion, on entering the marginal zone of the brain-wall, run in three main directions: one set makes directly for the mantle cells of the first neuromere,<sup>1</sup> and probably also of the second; another set runs longitudinally backwards, constituting the anlage of the spinal root V.; while a third set can be traced some distance forwards. The motor root arises some distance ventrally and becomes closely applied to the inner face of the ganglion, but remaining quite distinct from it. The ganglion in its upper part is dorsal to the vena capitis; lower down it comes to lie lateral to and closely opposed to this structure. It gives off three branches along which ganglion cells are carried for some distance. Especially is this the case with the ophthalmic branch, the root of which constitutes a finger-like process of the ganglion. This process is not distinct (as Elze) from the origin of the nerve. The ophthalmic nerve runs forward over the optic cup, crossing external to N. III., and curves downwards, keeping close to the circumference of the cup as indicated in fig. A. The detail of this branch and its relation to N. III. can be followed only with difficulty owing to the faintness of its loosely arranged fibres, but the following further points can be made out. On the right side, after crossing N. III., it expands in its sectional area. This expansion is due to a sprouting from its mesial surface, from which a branch runs through about seven sections ( $10\mu$ ) internal to the main trunk. The point of origin of this branch is separated from the anterior branch which N. III. drops down into the orbital pre-muscle mass by the anterior pole of this structure, and from this division of N. III. a small

<sup>1</sup> In the following account the neuromeres are reckoned exclusive of the first or "cerebellar" neuromere. Thus neuromere 1 is "neuromere a." of Streeter and "neuromere 2" of v. Kupffer, Bradley, Gräper, etc. See fig. 2.



fibre-bundle can be traced a short distance in the direction of the ophthalmic nerve. No ganglion cells are to be seen, but the picture suggests an early naso-ciliary branch with a commencing ciliary system. On the left side is a similar sprouting of the ophthalmic nerve, without a definite branch, and the arrangement of the mesodermal cells suggests a fibre connexion between it and N. III. Nervi mandibularis and maxillaris can be continued far into the first arch and its maxillary process respectively. The latter branch on approaching its termination is broken up into bundles by cells which, though mostly of the "sheath" type, are in part of ganglionic appearance. Its relation to the great superficial petrosal nerve will be later referred to. N. mandibularis shows no branching except for a short stump-like branch from its outer aspect twenty-five sections ( $10\mu$ ) from its origin. It receives the entire motor root.

Near its termination the nerve passes through a tunnel of strongly condensed deeply staining mesoderm, which is prolonged distally gutter-like along its outer and posterior aspect—the anlage of Meckel's cartilage. A portion of the nerve, however, splits off and runs a short distance on the outer side of this anlage. The chorda tympani branch is already in connexion with N. mandibularis, as will be described in connexion with N. VII.

N. VI.—The abducens nerve can be well seen on both sides in its peripheral course running forwards from the level of the otic vesicle, internal to the mandibular nerve, to end in the upper and posterior pole of the orbital pre-muscle mass. On both sides the nerve receives numerous radicles from the ventro-lateral border of the hind-brain internal to the otic vesicle and at a level corresponding with the fourth neuromere. At this point and posteriorly the relations become somewhat confused on the right side owing to an unfavourable plane of section. On the left side, although the fibre-bundles are in places exceedingly fine and occasionally disappear in one section to reappear in the next, a clear picture is nevertheless presented, so that the following description applies mainly to that side. The reconstruction of the nerve in fig. A, though necessarily somewhat schematic, is a faithful representation of the main course of the rootlets. A well-marked radicle, constituting the main posterior root of the nerve, arises from the lower part of the side of the brain internal to N. X. and immediately in front of the most anterior root of N. XII. and in series with it. The former is directed forwards, the latter backwards, while the two are separated by a small ascending branch of the vertebral artery. This radicle, at first directed also somewhat laterally, soon turns dorsally in the mesoderm on the side of the brain, and, reaching a level some twenty sections ( $10\mu$ ) higher than its origin, it joins another

bundle of fibres running from above and behind downwards and forwards. This bundle, traced upwards, rises to a high level close to the brain-wall until it reaches a point corresponding with the neural crest and about midway between the dorsal roots of N. IX. and N. X. Here it becomes very small, but before its final disappearance it seems to have a connexion by a fine rootlet with the brain-wall. This cannot, however, be stated with certainty owing to the minuteness of the structures and the unstained condition of the fibres. A short distance below the point where the bundle becomes lost it is joined by another fine fibre-bundle coming from behind and below. The latter bundle can be traced back to an origin from the anterior root of N. XII., and is apparently to be interpreted as a dorsal branch of that nerve. The above dorso-ventrally running nerve, after being joined by the main posterior radicle, runs downwards and forwards, receives a large root from the lower part of the fifth neuromere a short distance caudal to the otic vesicle, and is further joined to the main posterior radicle by a fine loop of connexion. Internal to the otic vesicle the bundle, now a nerve of relatively considerable size, receives two groups of radicles, one opposite its posterior border and the other a short distance farther forward. The abducens is therefore in connexion not only with the fourth neuromere but directly with the fifth and the brain-wall ventral to the sixth, and indirectly with the posterior unsegmented portion of the rhombencephalon through the anterior root of N. XII. The question of the origin of the sixth nerve with regard more especially to its connexion with a given neuromere has been very variously stated by different authors not only for lower vertebrates but also for man. An excellent summary of the whole subject has been recently given by Gräper. In the case of the human embryo most authors (except Broman, who derives it from the third neuromere) agree with Streeter in attributing the main origin of the nerve from the fourth neuromere (see footnote on p. 10). A posterior origin of the nerve is described by Elze (7 mm.), in whose embryo a radicle arises close to and in series with the roots of N. XII., and indeed a series of radicles extending between the abducens and N. XII has been more than once described in the literature. Bremer, in a more extended study of the aberrant roots of the two latter nerves, finds that in young human embryos it is by no means uncommon to find the gap between the two nerves filled in by a more or less segmental series of rootlets, some being directed not only backwards or forwards in a ventral direction but also laterally and dorsally. In a 10·2-mm. embryo one of these laterally running roots joins a separate bundle of N. IX. For an 11·5-mm. embryo he figures a condition very similar to that found in our case (fig. 4 in his paper). Gräper, working at the more intimate fibre connexions within

the neuromeral area of the rhombencephalon in several lower mammals, chick, etc., finds that in all cases the abducens is strictly confined in origin and point of exit to the fourth neuromere. He describes, however, in a 13-mm. sheep embryo, a bundle arising from between the fourth and fifth neuromeres and running ventrally and backwards to join N. IX. It would seem, therefore, from the foregoing more correct to regard this row of ventral roots, which occurs more or less normally in the young human embryo and bridges over the gap between abducens and N. XII., not as belonging morphologically to N. VI. proper, but as constituting transitory ventral branches of N. IX. and N. X. The fact that these roots are primarily connected with one another and with the nerves immediately in front and behind, and the further fact that they may possess dorsal branches corresponding with the dorsal divisions of the spinal nerves (Bremer), afford an explanation of the arrangement so frequently found. This interpretation is in agreement with the view of Gräper in that it derives the origin of the abducens solely from the fourth neuromere.

N. VII.—The ganglion of the facial nerve is wound spirally around the acoustic ganglion complex, and grooves the latter, lying somewhat internal above, then anteriorly and lower down on its outer aspect. The two cell masses are partly fused but are in part separated by mesodermal cells and, especially below, by the motor root VII. The central fibres of the ganglion (N. intermedius), in company with those of N. VIII., enter the marginal zone opposite the third neuromere, some running directly into the mantle layer of this neuromere, but large numbers taking a horizontal direction backwards and constituting the contribution of this nerve to the tractus solitarius. The motor root, which is small relatively to the size of the ganglion, arises a short distance below the point of entry of the sensory fibres. The trunk of the nerve runs backwards and outwards under the v. capitis lateralis and comes into relation with the first cleft. The connexion here is not in the form of a tubular placode formation, as is the case with the ganglia of IX. and X., but consists of a thick strand of ganglionic cells merging on the one hand with the cells of the ganglion and on the other with the thickened epidermis of the cleft. From the ganglion a short distance distal to this epibranchial organ a short branch is given off which has an independent connexion with that organ and constitutes the nervus epibranchialis described by Futamura in an embryo of 27 to 30 days (fig. 4). As the main trunk sweeps ventrally and caudally into the hyoid arch it drops off from the lower end of the ganglion an anterior branch, the great superficial petrosal nerve (fig. 4), which carries with it for some distance ganglionic cells. This nerve runs at first lateral to the a. carotidis interna, internal to the dorsal expansion of the first



pharyngeal pouch, across the roof of the pouch itself anteriorly, and into the maxillary process lying close to the epithelium of the roof of the mouth cavity (fig. 5). After running a short distance downwards into the maxillary process, it shoots almost horizontally in the sections as a well-marked bundle across the space separating it from the terminal bundles of n. maxillaris, without establishing any traceable connexion. There is as yet no definite accumulation of ganglion cells in this region. The chorda

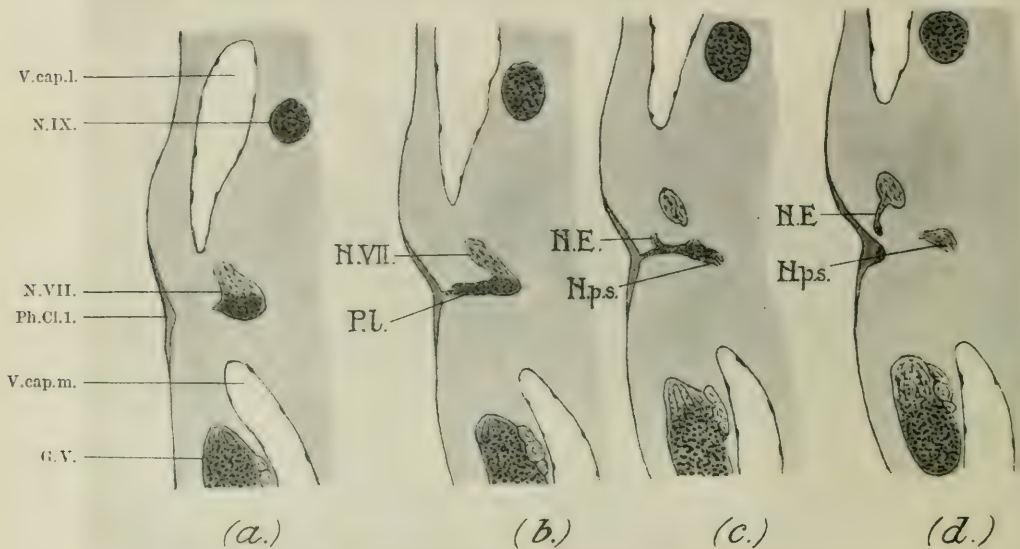


FIG. 4.—Four sections at the level of the placode of N.VII. on the right side.  
(a) Section 229 ; (b) section 232 ; (c) section 234 ; (d) section 336.

tympani is present as a large branch from the trunk of the nerve (fig. 5), running into the mandibular arch in the angle between the epithelium of the first cleft and the endothelium of the first pouch, which meet above it in the cleft membrane. It ends by dividing into two main branches which are directed mesially in the condensed mesoderm of the floor of the mouth, but before this final division it gives off a small branch which curves outwards to connect with n. mandibularis as it runs in the mesodermal Meckelian "gutter" described above. This connexion is not apparent on the right side, although a similar branch is present. The nerve trunk finally terminates in a sharply outlined mass of condensed tissue—the hyoid pre-muscle mass, described by Futamura at this stage.

The acoustic complex is markedly differentiated histologically in its upper and lower segments; for while the upper portion resembles the adjacent ganglion VII. and the spinal ganglia generally, the cells in the

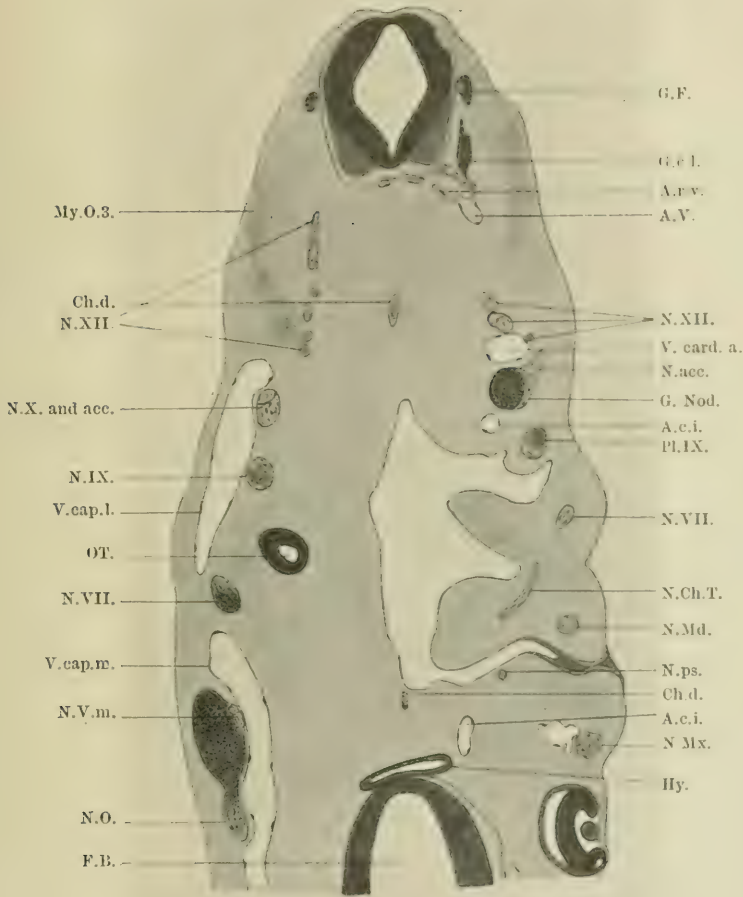


FIG. 5.  $\times 25$ .

lower portion are smaller, more darkly staining, and more widely spaced. This latter "cochlear" segment overlaps the upper "vestibular" segment especially on its outer side, but also internally, so that the vestibular segment has the appearance of being inserted into it from above. The

cells of this lower cochlear portion further fuse in part with the epithelial wall of the otic vesicle, destroying its sharp outline and leaving no definite line of demarcation between the two structures. Fibres are continued upwards from it internal to the vestibular ganglion, and constitute the young cochlear nerve. The central fibres from the upper part of the ganglion join the marginal zone opposite the third neuromere in company with the fibres from ganglion VII.

N. IX.—The ganglion of Ehrenritter is relatively insignificant, and consists of a small collection of cells almost entirely confined to the lateral aspect of the nerve. Its central fibres join the marginal zone of the hind-brain, some entering the mantle layer of the fifth neuromere, while many turn backwards and upwards, causing a thickening in the "Randschleier" towards the point of entry of the central vagal fibres. The motor root is distinguishable as a small bundle arising a short distance ventrally. The nerve is continued distally internal to the v. capitis lateralis (fig. 5, right side) as a fibro-cellular strand in which the fibres predominate, the cells being apparently all of the "sheath" type. As it approaches the level of the dorsal apex of the second pharyngeal pocket, ganglion cells begin to appear again, and soon the whole cross-section of the nerve consists of a dense mass of darkly staining nuclei forming a large ganglion—the ganglion petrosum. In this structure a definite fibrous (motor) element is indistinguishable as such, in contrast with what has been noted in the case of the ganglion V. and ganglion VII. The ganglion in its lower part comes to be closely applied to the posterior wall of the second pharyngeal pocket (figs. 5 and 6), and here, on the left side, appears a short sprout from its anterior face. This is the only indication of a nervus tympanicus, the presence of which has been noted by Futamura at this stage (27 to 30 days). On the right side is a small but very definite fibro-cellular connexion between the ganglion petrosum and the upper part of the ganglion nodosum. This connexion is absent on the left side. According to Streeter, such a connexion between N. IX. and N. X. is absent in embryos up to 7 mm., and usually also in embryos of that stage, while in slightly older embryos the two nerves come into close relation and may be linked together. Elze in a 7-mm. embryo finds no such connexion, and both His and Streeter figure it at 10.2 mm. Hence in the embryo under description, although the two nerves are still separated by an appreciable interval at the point of connexion, the latter on the evidence must be regarded as of a secondary nature. The nerve trunk, traced down into the third arch, runs lateral to the a. carotidis interna, and gradually becomes free from ganglion cells on its inner aspect, but on its lateral aspect the cells gradually merge into a well-marked placode. The latter consists of a tubular process



of epithelium, opening below on the lateral face of the third visceral arch in the deeper part of the second cleft or "ductus branchialis II." The opening is about  $140\mu$  in diameter from above downward, and from it a finger-like process extends up to the outer side of the distal end of the ganglion (fig. 5), its tip being embedded in the latter structure, so that histologically the two are continuous. A lumen extends through the process for a distance of  $90\mu$  from the mouth of the placode. From this point the nerve curves forwards and downwards to end just lateral to the (medial) thyroid anlage. In this part of its course it is situated some distance anterior to the third aortic arch, but drops off on the left side, a short internal branch which runs some distance ventrally in close relation to the artery. On the right side (fig. 6) two such branches are present.<sup>1</sup>

N. X. and N. XI.—The development of the vago-accessory complex has been described in detail by Streeter. Nevertheless, a few points come up for special mention, especially as our embryo falls in the gap between the 7-mm. and 10-mm. embryos of his series. The general outline of the developmental stage can be seen in the reconstruction (fig. A). A vagus root-ganglion has been definitely differentiated from the neural crest of the hind-brain, its central fibres entering the sixth neuromere (fig. 2). The more posterior part of the crest is represented by four or five ganglionic clumps along the well-developed accessory motor portion of the complex, which clumps gradually diminish in size from before backwards. The accessory nerve is first found at the level of the third cervical segment, from which point it runs cephalad internal to the second cervical ganglion. Almost at the level of the I.C. ganglion, but slightly distal to it, it passes external to a small fibre-bundle coming dorsad and somewhat caudad from this ganglion. It then develops on its outer and ventral aspect a dense ganglionic clump, corresponding in size with the I.C. ganglion itself, but having no connexion with this latter structure or with the hypoglossal rootlets. This aggregation of nerve-cells might be regarded either as a detached portion of the I.C. ganglion, an arrangement which, according to Streeter, frequently occurs; or, on the other hand, it might with quite as much probability be looked upon as a Froriep ganglion. Its position some distance caudal to the rootlets of N. XII. is not against this view, for the process which, as Streeter suggests, has brought about the breaking up of the neural crest into clumps, viz. the growth of the intervening fibre-tracts, will obviously produce its greatest effect in the case of the most

<sup>1</sup> In the profile reconstruction N. IX. seems to run in the second arch; this is due to the fact that while the nerves are projected on the mid-sagittal plane, the visceral arches, etc., are represented in *surface* outline, so that the deeper relations, viz. the obliquity of the second cleft, are not shown.

posterior member of the series and thus cause marked caudal displacement. In a 10.2-mm. and in a 14-mm. embryo Streeter figures the ganglion in a position well caudal to the most posterior rootlet of XII. Its shape furthermore corresponds with the general description given for a Froriep ganglion, in that it tapers off anteriorly in contradistinction to the

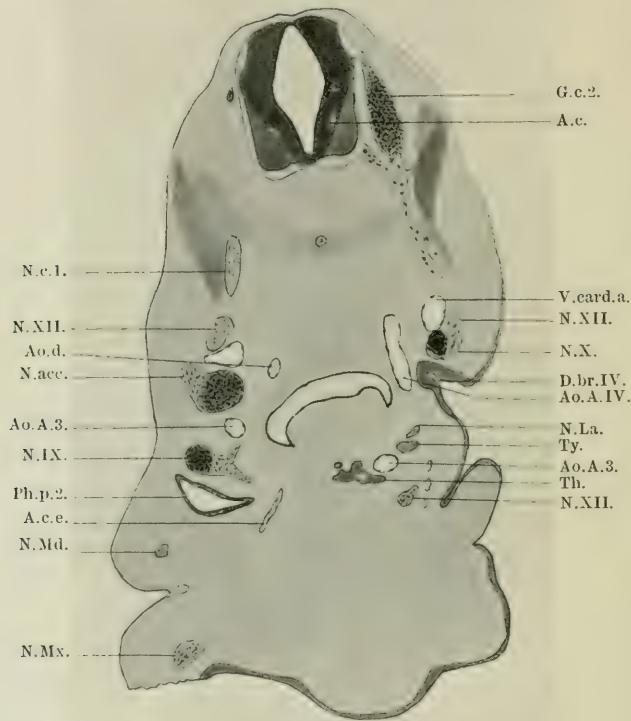


FIG. 6.  $\times 25$ .

accessory cell clumps. There is no well-defined Froriep formation on the right side, where the I.C. ganglion is better developed and extends dorsally to the accessory nerve, sending most but not all of its central fibres internal to this structure. The ganglion jugulare, with the accessory motor root applied to its posterior aspect, is continued down as a fibro-cellular strand, free from ganglion cells, to the ganglion nodosum (figs. 5 and 6). The v. capitis lateralis crosses the trunk of the nerve laterally and then runs behind it. The motor portion leaves the upper part of the ganglion

nodosum and passes dorsally and laterally, crossing the vein, N. XII. and N. I.c., to end in three branches in a condensed mesenchyme,—the anlage of the sterno-cleidomastoid muscles. The lower part of the ganglion lies dorsal to the third and fourth pharyngeal pockets, and opposite the fourth visceral arch it gives off a large branch which curves downwards and inwards in the anterior part of this structure (fig. 6, left side) anterior to the fourth aortic arch, to end dorsal to the ventral aorta close to the hypoglossal nerve. This is the superior laryngeal nerve, and it gives off, as is best seen on the right side, an external branch which runs in the posterior part of the arch external to the artery, and represents in all probability the external branch of the superior laryngeal nerve of the adult. The placode in connexion with N. X. is a short epithelial cul-de-sac continued from the upper end of the fourth visceral cleft. The cells of its tip blend with those of the ganglion at the level of the origin of the superior laryngeal nerve. The vagus trunk then passes caudad lateral to the sixth aortic arch, is crossed by N. XII., and comes to lie in the mesodermal tissue lateral to the œsophagus and trachea (comp. figs. 6 and 7). It can be traced well beyond the tracheal bifurcation (fig. 10), where it breaks up into branches which run to the developing bronchi, and others which form a plexus around the œsophagus containing much syncytial sympathetic tissue, as will be later referred to in connexion with that system. A terminal ramification on the fundus of the stomach cannot be made out.

N. XII. arises by a series of ten or eleven rootlets from a longitudinal thickening of the mantle layer already described as a prolongation of the anterior horn anlage into the hind-brain. The series, individually separated by ascending branches of the vertebral artery, extends from the level of the vago-accessory trunk to within a short distance of the origin of the ventral nerve-root C.I., the anterior rootlet, as has already been noted, having a fine loop connexion with the origin of N. VI. These rootlets unite to form three bundles, which in turn fuse together to form the main hypoglossal trunk. The two fan-like anterior occipital myotomes are in lateral relation to the rootlets, somewhat widely separated above but in contact with them below, where the first myotome sends a wedge of pre-muscle tissue between the two anterior roots. The third occipital myotome lies for the most part caudal to the posterior group but overlaps it. From the most anterior root on the left side a large branch detaches itself, running at first laterally across the back of the anterior cardinal vein and then caudally postero-lateral to this vessel (fig. 5), so that dorsal tributaries of the latter separate the nerve from its parent trunk. This aberrant nerve, which is altogether absent on the right side, rejoins the main trunk of the hypoglossus below. The latter



lies at first behind the ganglion nodosum, separated from it by the anterior cardinal vein. It then winds spirally around these structures, is crossed by the accessory nerve, and turns sharply upwards and medialwards to end near the (median) thyroid anlage (fig. 6). At the lowest point of the bend it drops off a branch which can be followed some distance caudally, dorsal to the pericardium and left auricle, to end in the mesodermal anlage of the

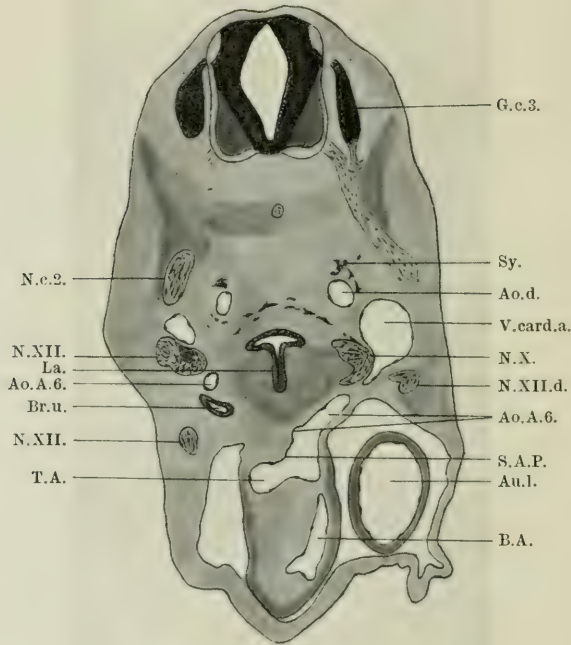


FIG. 7.  $\times 25$ .

infra-hyoid musculature—the descendens hypoglossi (fig. 7, left side). The hypoglossal trunk is joined posteriorly by the first two and part of the third cervical nerves, the arrangement being essentially similar to that described and figured by Elze and Streeter. In one important point, however, the arrangement indicates an advancement on the Elze (7 mm.) embryo, inasmuch as the cervical contributions join the trunk of N. XII. relatively much lower down; in fact, the C. III. fibres connect with the ramus descendens rather than with the main trunk, so that we are here a step nearer an “ansa” formation typical of a 10-mm. stage. From the

proximal end of the nerve trunk and from the distal ends of its constituent roots there extend towards the dorsal aorta cords of typical synectial sympathetic cells ("cellular rami") similar to those to be later described in connexion with the spinal nerves. Dorsal to the aorta in each section there appears at this level a small collection of synectial tissue constituting a cephalic prolongation of the sympathetic cord. We are here, therefore, dealing with the anlage of the upper end of the first cervical ganglion, the connecting cords probably representing the early stage of the hypoglossosympathetic connexion of the adult.

*The Spinal Nerves.*—Dorsal roots. The neural crest extends unbroken from ganglion C. II. to within a short distance of the tip of the spinal cord. In the cervical and dorsal region it has undergone almost complete segmentation into ganglia, which, however, remain connected by a cellular bridge. The C. I. ganglion has no connexion with the second on either side. As we go caudal to the lower lumbar region the connecting bridge becomes relatively more important in size than its ventral ganglionic offsets, while still further caudal the ganglia are represented only by the teeth of the serrated ventral border of the crest. In all about thirty-four dorsal spinal ganglia are definitely demarcated on either side. In general they are connected dorsally with the thickened ridge of marginal zone containing the early postero-lateral fibre columns in which the entering dorsal root-fibres assume for the most part a longitudinal arrangement. The distance between ganglion and thickened marginal zone diminishes as we go back, until ultimately, in the lower lumbar region, the dorsal border of the crest comes into direct contact with the postero-lateral ridge through cellular ganglionic processes, containing a few fibres. Still further caudal the dorsal border of the crest rises towards the dorsal aspect of the spinal cord, higher at some points than at others, so that, although there is here no fibrillation, the dorsal border of the crest shows a serration similar to the ventral border. This picture suggests that in the ventral migration of the neural crest some parts lag behind at regular intervals, this process commencing before the dorsal border has reached the level of the future thickened postero-lateral ridge and giving rise to dorsal processes of the crest itself. When these dorsal serrations reach the level of the ridge they become here attached to the spinal cord by fibres which are at first very short, subsequently becoming longer owing to the differential growth of the parts. In other words, it would scarcely seem quite accurate to regard the first dorsal rootlets as a secondary connexion through a sprouting of fibrous processes between two relatively widely separated points. Ventral root-fibres can be definitely noted as far caudal as the first coccygeal segment, the more posterior groups of the series arising from an undifferentiated



neural wall, the more anterior (as far caudal as S. II. segment) from a definite anterior horn anlage. The ganglia are connected with the ventral roots in the cervical and dorsal regions by well-marked fibrous processes in which neurocytes (Kohn) are scattered. In the lower lumbar and more caudal segments the ventral root fibres run through the ventral poles of the ganglia (figs. 20 and 21). This suggests a process similar to that occurring in the dorsal poles of the ganglia, viz. the pole of the ganglion itself comes in the first instance into immediate relation to the ventral root and short fibre connexions are established, gradually becoming longer as growth of the roots and cord takes place. An early dorsal branch of the complete spinal nerve is present from C. II. to C. VI. inclusive on the left side (see fig. 6). These branches are short, directed laterally, and spread out fan-like to enter the inner face of the myotome. There is none in connexion with C. I., and that in the case of C. VI. is very small. On the right side they are not so well seen owing to the slight obliquity of the sections, but there is a well-marked dorsal branch from C. I. on this side. The spinal nerves are connected with one another by anastomoses down to S. II., those between the individual cervical nerves and D. I. being especially large. The anastomotic loops closely invest the ventral aspect of the root of the membranous costal processes. In the dorsal region they are much finer, but that between D. XII. and L. I. shows a definite increase in size, while the individual lumbar nerves and the first two sacral nerves form a thick band of connexion among themselves. The nerves are well advanced on their ventral course in the lateral wall of pericardium and coelom, but show no division into terminal lateral and anterior divisions. The phrenic nerve arises from the anastomoses between C. III., IV., and V. nerves, and runs ventrally and caudally towards the pleuro-pericardial membrane, which it just fails to reach (figs. 9 to 12). It lies at first dorsal to the anterior cardinal sinus; then, hooking around the termination of the subclavian vein, it passes almost horizontally in a ventral direction lateral to the termination of the posterior cardinal vein, and at its termination lies dorso-lateral to the duct of Cuvier (fig. 9). The innervation of the upper extremity is in the form of a plate-like expansion which projects laterally into the root of the limb from the anastomoses between C. V., VI., VII., and VIII., beyond which the individual nerves project ventrally towards the lateral wall of the pericardium without actually reaching it (rami pectorales). This plate is best marked opposite C. VI. and VII. nerves, and divides into two leaves, a dorsal and a ventral, which show a condition of differentiation intermediate between Elze's 7-mm. embryo and his Embryo II. (fig. 452, Keibel and Mall). The dorsal plate, besides its main process (radialis), has nearer its oral edge a short process directed towards the pre-axial

border of the limb. From the ventral leaf of the plate musculo-cutaneous, median, and ulnar processes are distinguishable. The latter, after a short course as a single trunk, divides on both sides into two branches which can be followed some distance distally in close relation to the marginal (brachio-ulnar) vein in the postaxial border of the limb. The nerve and its branches lie anterior and ventral (*i.e.* pre-axial) to the vein. The subclavian artery, as is described in greater detail below, springs from the seventh dorsal segmental artery and pierces the nerve plate between C. VI. and C. VII. nerves. Between the dorsal and ventral leaves it gives off a branch towards the radial nerve, and soon breaks up into two branches, a larger accompanying the median and a smaller accompanying the ulnar nerve. The main vein of the limb (*vide infra*) runs along the postaxial border, then orally dorsal to the dorsal leaf of the nerve plate in its whole extent (fig. 12 *et seq.*), and crosses anterior and ventral to the phrenic nerve to join the cardinal sinus opposite the duct of Cuvier. The basis of the lumbosacral plexus is represented by the strong anastomoses between the lumbar and sacral nerves. This connecting band expands somewhat opposite the hind limb into a slightly differentiated plate which sends processes for a short distance into the root of the limb.

*Sympathetic Nervous System and Anlage of the Suprarenal Cortex.*—A definite chain of sympathetic—or sympatho-chromaffin (Zuckerkaudl)—tissue is present from the level of the ganglion nodosum to the level of the umbilical arteries. Further forward in the head region and in connexion with the more anterior cerebral nerves, viz. between the distal extremity of the superficial petrosal nerve and the n. mandibularis, a similar type of tissue is suggested in the form of scattered cells, which cannot however be ascribed with any certainty to the sympathetic system. The nerve bundle, “almost entirely free from ganglion cells,” which Elze (7 mm.) describes as lying medial to the trigeminal ganglion and which he provisionally regarded as of sympathetic nature, corresponds exactly in position and appearance with N. VI. in our embryo, and is doubtless in the former case also a portion of that nerve in its peripheral course. The sympathetic cord has a fixed position throughout, lying at first dorso-lateral to the a. carotis interna, then in a similar relation to the aortic roots and later to the aorta itself. The histological characters of its constituent cells are not absolutely constant, but there is always the frequently occurring mitotic figure, the darkly staining nucleus and protoplasmic body provided with short processes, and with a tendency in common with its neighbours to run together into a syncytium as described by Kohn, Zuckerkaudl, and others (Pl. I. fig. 2). In the cervical region there is a commencing ganglion formation, the cord appearing in some sections as a few scattered cells and

in others as a dense clump with a remarkably definite outline. This appearance is less evident in the dorsal and lumbar regions owing to the fact that the cord here gets broken up into a looser network by the insertion of the brush-like ends of the rami communicantes. The first fibrous ramus appears in connexion with N. C. VIII. (fig. 15). More orally the cord is frequently connected with the cervical nerves, and then anastomoses by loose chains of sympathetic cells constituting the "cellular rami" described by Kohn for the rabbit (Pl. I. fig. 2). Such a cellular ramus is present in the case of N. C. I., and, as has already been described, similar chains of cells appear between the ganglion nodosum, the hypoglossal rootlets, and the sympathetic cord at these levels. Fibrous rami are present from C. VIII. to L. III., caudal to which the rami again become cellular. Here, however, in the narrow space between the aorta and the spinal nerves the sympathetic chain becomes closely applied to the latter, so that the term "ramus" can scarcely be employed to describe the connexion. Where a fibrous connexion is present it takes the form of at least two, and in many cases three, distinct bundles from each spinal nerve, the more posterior bundle often fusing with the anterior bundle of the nerve next caudal before it reaches the sympathetic chain (fig. 21). Especially is this the case with the lower dorsal and upper lumbar nerves. The rami spread out into an almost continuous brush on reaching the cellular chain, loosening it up into a network of cells rather than a close syncytium. In the lumbar region, where the cord is more longitudinally cut in the sections, the protoplasmic processes of the cells can be seen to be directed longitudinally within it, but it is questionable whether distinct nerve fibres are present apart from the entering fibres of the rami communicantes. Anlagen of the coeliac, aortic, and hypogastric plexuses are represented by a ventral streaming of fibres and sympathetic cells from the chain as well as directly from the rami. This fibro-cellular migration is most marked around the origins of the coeliac and omphalo-mesenteric arteries (figs. 17, 18, 19), but is present in some degree down to the level of the umbilical arteries. The fibres and cells pass ventrally around the aorta, between it and the Wolffian body, and more orally they are closely applied to the inner face of the anlage of the suprarenal cortex. A fibre connexion of the sympathetic migrations of opposite sides across the anterior aspect of the aorta cannot be made out, but syncytial clumps of sympathetic cells are present in this position, especially around the origin of the coeliac artery. Similar clumps extend into the root of the mesentery of the stomach and intestine. Surrounding the whole length of the oesophagus, and especially on its dorsal aspect, are numerous collections of darkly staining syncytial tissue, undoubtedly sympathetic, in a position similar to that of the "Hals-aorten-



geflecht" figured by His for a fourth-day chick, and constituting a myenteric plexus in combination with numerous small branches of the vagus (fig. 7 *et seq.*) Similar ganglionic collections, but fewer in number, are present at the lower end of the trachea around its bifurcation, also in association with vagal filaments, and represent the anlage of the cardiac plexus.

The anlage of the suprarenal cortex is present in the first five dorsal segments. It is situated between the aorta medially, the mesonephros laterally, and the Wolffian arteries dorsally (fig. 16 *et seq.*). It does not reach the dorsal pillar of the pleuro-pericardial membrane anteriorly as it does in slightly older stages (Zuckerlandl) Histologically its component cells are markedly differentiated from the surrounding mesoderm cells, and show an "epithelial" character, the nuclei being larger and more deeply staining and the cells rounder and with a closely aggregated arrangement. Caudally the cell condensation is separated from the coelomic epithelium by a relatively wide area of undifferentiated mesoderm, but orally the relation is more intimate, the intervening mesoderm containing numbers of cells of the above type which connect the anlage with a broad ridge of the coelom between the mesonephros and the root of the mesentery. The mesial face of the anlage has closely applied to it the ventrally streaming sympathetic fibres and cells (figs. 17, 18, and 19). In its substance are numerous small veins (see fig. 18), which can be frequently seen to open into the posterior cardinal sinus as mesial ventral tributaries of this vessel. These latter branches more caudally are concerned in the formation of the subcardinal vein (*vide infra*). Notwithstanding the close relation of the Wolffian arteries to its dorsal surface, no branches of these vessels could be seen entering the anlage.

#### ORGANS OF SPECIAL SENSE.

*The Olfactory Organ.*—The wax model of the nasal organ (Pl. I. fig. 3) falls naturally into the series of models by Peter, figured in his *Atlas der Entwicklung der Nase und des Gaumens*, and resembles his model of a 9.2-mm. embryo. The nasal area is sunken into a pit, looks laterally as well as ventrally, and is surrounded by a well-developed rampart which is best marked on the lateral aspect and here forms the lateral nasal process. Only anteriorly is the boundary wall indistinct, but even here there is an appreciable elevation demarcating the pit from the general surface. The medial nasal process is most prominent posteriorly—processus globularis (Keibel)—and is continued back along the ventral surface of the head some distance beyond the posterior margin of the pit. Here it is bounded on its lateral aspect by a still shallow oblique groove which is continued forwards

to cut into the posterior margin of the pit and backwards and inwards along the future roof of the mouth—the ventral limiting groove of the maxillary process. The external limiting groove of the maxillary process, or naso-lacrimal groove, is continued downwards and forwards from the optic anlage and cuts into the nasal margin a short distance anteriorly and laterally, so that the tip of the maxillary process forms the postero-external boundary of the pit for a short distance, and separates the lateral from the mesial nasal process.

The nasal pit is continued backwards and somewhat inwards as a blind sac for a distance of about  $110\mu$ . The floor of the sac is formed by a thick complete raphe of epithelium, the ventral border of which is attached along the groove which we have termed the ventral limiting groove of the maxillary process, and is continuous with the epithelium covering this process and the medial nasal process. There is no wide groove separating the two processes as in His's figure of a twenty-nine days embryo, the accuracy of which Hochstetter and Keibel have questioned. Such a groove is further absent in Peter's series. A comparison of the model with that by Peter for a 10.5-mm. embryo shows that the ventral limiting groove is much shallower and less marked than in the latter owing to the fact that the two processes are less pronounced. The groove is thus a secondary formation, and in neither case can it be regarded as a gutter connecting the hinder end of the nasal pit with the roof of the stomodæum. In general the appearances confirm the view of an early fusion of the maxillary and medial nasal processes to form the posterior boundary of the nasal pit and the "primitive Gaumen," the fusion taking place from within outwards (Keibel) as the respective processes expand. A bridging over by these two processes of a pre-existing groove connecting the nasal pit with the stomodæum, as described by His, is not compatible with the form of the parts at this early stage. The anlage of the organ of Jacobson is present in its earliest form (fig. 8). It does not appear on the model, but can be observed as a faint grooving of the epithelium of the medial wall of the nasal pit, similar in appearance and position to that figured in the Normaltafel of Keibel and Elze (fig. 32) for an embryo of 8.5 mm. The latter is the earliest in which this anlage has been noted.

*The Eye.*—The development of the eye marks a stage in advance of that of Hochstetter's 7-mm. embryo, described in detail by Elze and reproduced as fig. 169 of Keibel and Mall's *Text-book*. The optic cup is connected with the diencephalon by a short widely-open pedicle. The laminae of the cup are still separated by a wide interval. The outer lamina consists of two or three irregular layers of nuclei and contains traces of pigment. The lamina inversa is greatly thickened and has become differentiated into



two layers, an outer radial layer of protoplasmic strands and nuclei resembling the radial layer of the neural wall, and an inner fibre layer also radial but cell-free except for a few nuclei scattered in each section. The

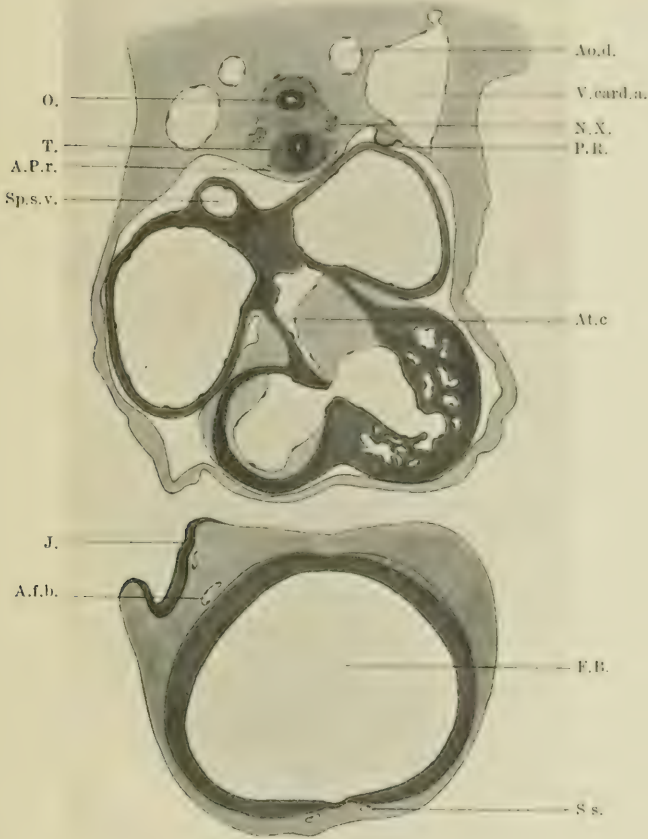


FIG. 8.  $\times 25$ .

edge of the cup (fig. 5) is closely apposed to the surface epithelium dorso-anteriorly (*i.e.* relatively to the long axis of the embryo). Besides the mesodermal cells surrounding the blood-vessels and those flowing over the edges of the cup, the antrum cupulae contains scattered cells which may have been derived from these latter sources, or, as pointed out by Lieberkuhn, from the migrating (!) cells of the otherwise cell-free inner zone of the

lamina inversa. The chorioid fissure is open along its whole length, but the distal ends of the fissure come very close together on the right side.

The lens vesicle is quite closed, its external contour being complete. Its cavity contains degenerating cells lying free and partly clumped together. Its posterior wall is thickened and differentiated into an outer cellular and an inner radial cell-free layer indicating a commencing fibre formation. It is still in contact with the surface epithelium on both sides. In general it has a circular outline in the sections, but has the appearance of being compressed between the lamina inversa retinae and the surface. This is probably due in part at least to the manipulation of fixing and embedding. At the level of contact with the surface epithelium the lens anlage has a flattened pear-shaped outline, the narrower end of the pear causing a protrusion of the surface. The surface epithelium is one-layered over the point of closure in a few sections of the left side, and consists of cubical cells; elsewhere on this side and entirely on the right it is two-layered. The epithelial layers, however, undergo a modification in two respects in the immediate neighbourhood of the point of closure: mitotic figures become more frequent in both layers, and the nuclei of the outer layer lose their typical flattened form and assume the round form seen in the cubical cells of the stratum germinativum. It is not definitely ascertainable whether the single layer above referred to, and which Elze describes for both sides of the 7-mm. embryo, is to be regarded as a continuation of the outer or the inner layer. The impression suggested by a study of the modification of the surrounding epithelium is that it rather represents *both* layers. In other words, the process of closure might be regarded as consisting of a primary growing over of one layer, viz. the superficial layer (Elze), followed later by the other layer; or we might, with greater probability, premise a resolution of the two-layered epithelium into its primary one-layered form at its "growing-point." When the closure has been effected by the active growing over of this single layer, the latter then differentiates once more into its two layers.

The a. hyaloidea is represented by a large sinus-like blood space lying in the anterior part of the chorioid fissure, projecting into the antrum cupulae and coming into contact with the lens vesicle. It is connected distally with a capillary plexus around the edge of the optic cup, and proximally with a capillary system lying along the pedicle, and through this apparently with the capillary vessels of the maxillary process. An arterial branch, to be later referred to, springs from the a. carotis interna over the optic stalk (a. ophthalmica), but there is no connexion present between this vessel and the anlage of the a. hyaloidea except an indirect one through the capillary plexus on the outer face of the optic cup.

*The Ear.*—The anlage of the labyrinth lies lateral to the fourth neuromere of the hind-brain. The ductus endolymphaticus (fig. 2) is about  $500\mu$  in length on the left side, and on the right  $700\mu$ , the disparity in length being probably largely apparent and due to the obliquity of the plane of section. It opens into the otic vesicle proper on its medial aspect about  $130\mu$  below the tip of the latter. In its upper half it shows a roughly triangular outline on cross-section, the epithelium at the anterior and posterior angles being markedly thickened, forming sharp ridges on its external aspect. This occurs to a less extent at the outer angle. In its lower half the angles become rounded off and the outline oval. The tip and most of the outer wall consist of a single layer of epithelium, the inner wall, like the rest of the labyrinthine anlage, being 2 to 3 cells thick. In the otic vesicle itself a lower, more tubular cochlear segment can be distinguished from an upper vestibular portion, in which the anlagen of the anterior and posterior semicircular canals are indicated by a pouching of the wall. A bulging of the lateral wall somewhat lower down suggests a commencing external canal. The lower end of the vesicle is widely separated from the first pharyngeal pouch, which lies ventrally and laterally. In the intervening mesoderm runs the a. carotis interna with the dorsal root of the incomplete second aortic arch. In the primitive tympanic cavity there is an anterior and posterior tympanic recess separated by a groove, the groove for the tensor tympani, corresponding with Hammar's model of an 8-mm. embryo (fig. p. 274 of Keibel and Mall's *Text-book*). From the anterior tympanic recess a short groove is continued downwards and forwards on the roof of the pharynx. The relation of the n. chorda tympani to the tympanic cavity has been already referred to in connexion with that nerve.

#### THE ALIMENTARY CANAL AND ITS DERIVATIVES.

On the floor of the pharynx are present the tuberculum impar, with immediately lateral to it on either side a swelling, situated on the ventral end of the first visceral arch. The copula is well marked, and is continuous back into high arytenoid folds. The hypophysis has a wide connexion with the roof of the pharynx, and is closely applied to the floor of the diencephalon (fig. 5). It is flattened dorso-ventrally and shows a slit-like lumen. Near its distal extremity ends the chorda dorsalis, from which it is separated only by a small interval. Its apex is bifurcated and is continued into two short solid horns.

The first pharyngeal pouch presents nothing for description further than has been mentioned under the primitive tympanic cavity. The second epidermal cleft runs very obliquely forwards as well as in a medial direction, and is continued into a well-marked ductus branchialis II. (Rabl)



into which, as has already been noted, opens the placode in connexion with N. IX. The third pharyngeal pouch is much smaller than the two preceding, and has a short dorsal and a long ventral process, the lumen throughout being reduced to a mere slit (Pl. I. fig. 4) by the thickness of its walls. Its closing membrane is situated at the bottom of the sinus cervicalis. The pouch is connected with the pharynx by a still widely open ductus pharyngo-branchialis III. The differentiation of the anlagen of the epithelial bodies and thymus is well advanced, and agrees with the descriptions of Groschuff, Kohn, and Maximow. The ventral prolongation of the pouch—or thymic anlage proper—is continued ventrally and medially, at first dorso-posterior to the third aortic arch, to end close to the thyroid anlage (fig. 6) on the lateral aspect of the truncus arteriosus. Its wall consists of several layers of densely packed cells, the posterior wall being thicker than the anterior. This thickening is continued on to the posterior and dorsal wall of the pouch itself. The anterior and outer walls of the latter have quite a different histological structure. Pl. I. fig. 4 is a drawing of a horizontal section through a portion of the pouch. A lumen is practically non-existent. The posterior wall shows the close arrangement of the nuclei in the thymic thickening, while the loose arrangement in the anterior wall offers a marked contrast. Here the smaller but more darkly staining nuclei are studded through a pale (chromophobe) vacuolated protoplasmic syncytium in an irregular manner. This portion of the wall of the pouch constitutes the anlage of the “epithelial body III.” (Kohn) or parathyroid.

The “caudal pharyngeal pouch complex”—to use the term suggested by Grosser—consists of a relatively involuted fourth pouch with short dorsal and ventral pockets. The anterior wall of the pouch and the outer wall of the ventral pocket show the same histological differentiation as has been above described for the epithelial body III, and constitute the anlage of the epithelial body IV. There is no definite “thymic” thickening present as in the case of the third pouch. There appears further in connexion with this pouch a comparatively long ventro-caudal tubular process at first sight similar to that of the third pouch, but a closer examination of the sections shows that the resemblance is merely superficial. The process under consideration is not a direct continuation of the ventral pocket, which is itself small, but it arises more dorsally and laterally from the body of the pouch. Furthermore, a distinction is indicated by its relation to the aortic arches; for whereas the ventral prolongation of the third pouch is in close dorso-posterior relation to the third arch, the structure in question is separated by a wide interval from the fourth arch and is in close antero-ventral relation to the sixth arch (fig. 7). This arrangement suggests the

former presence and later disappearance of such a vessel as Elze (7 mm.) describes as running "close to the ventral wall of the postbranchial body," namely, the rudimentary fifth aortic arch, which vessel in our embryo is represented only at its extreme dorsal end. The structure under description is to be regarded, therefore, as the derivative of a fifth pouch or "ultimobranchial body" of Tandler. Its ventral extremity approaches the pericardium closely (fig. 7), and lies about  $300\mu$  caudal and lateral to the thyroid anlage.

The thyroid anlage, as shown in fig. 6, is bilobed, with a dorsal and a lateral sprout from each lobe. A lumen is present in the proximal part of the left lobe. The component cells, of which the nuclei are large, round, and darkly staining, are closely packed together and show a commencing column formation. The distal end of the thyro-glossal duct can be followed proximally through nine or ten sections ( $10\mu$ ) as a solid epithelial cord. The anlage as a whole lies in the apex of the V formed by the third aortic arches overlapping these vessels and the bifurcation of the truncus arteriosus.

*The Larynx and Lungs.*—The arytenoid folds are well developed. The lumen of the laryngeal cleft is to a large extent obliterated by a fusion of its walls (fig. 7), but orally a small lumen remains, while posteriorly there is a slit-like communication between œsophagus and trachea. The lumen of the trachea, at first merely a cleft like that of the larynx, soon broadens into an oval, and later presents a circular appearance. Further caudally its form varies in cross-section from a circle to an oval, with the long axis either lateral or antero-posterior. The bifurcation occurs in the sixth cervical segment. The condition of differentiation of the pulmonary sacs, as ascertained from an antero-posterior graphic reconstruction, shows an advance on Narath's figure for a 7-mm. embryo (fig. 342, Keibel and Mall), and on Elze's model (*ca.* 7 mm.) (*cf.* figs. 10-13 and 15). The left stem bronchus has a large lateral bud directed somewhat dorsally (fig. 11)—the "first ventral bud" of Aeby, or "lateral" bud of His—and ends in a swollen but undifferentiated flask-shaped extremity. From the right stem bronchus spring an apical or eparterial bronchus (fig. 12) and a first ventral bronchus bud (fig. 13), the latter of which is somewhat constricted at its origin. Immediately caudal to the origin of the ventral bronchus on this side, the stem bronchus, as can be seen in fig. 13, shows an expansion in a dorsal direction, indicating the formation of a dorsal bronchus bud at this point. The mesodermal lung anlage shows a corresponding lobing on its outer surface. The relation of the pulmonary artery to the primary bronchi and their branches is described below (*cf.* Pulmonary Artery).

The œsophagus is at first crescentic in outline, with the concavity



directed ventrally; lower down it becomes either circular or elliptical. The wall consists of three or four layers of nuclei grouped for the most part in the middle thickness, leaving an outer basal layer free from nuclei, and an inner layer with few nuclei but with relatively numerous mitotic figures. The epithelial tube is surrounded and closely invested by con-

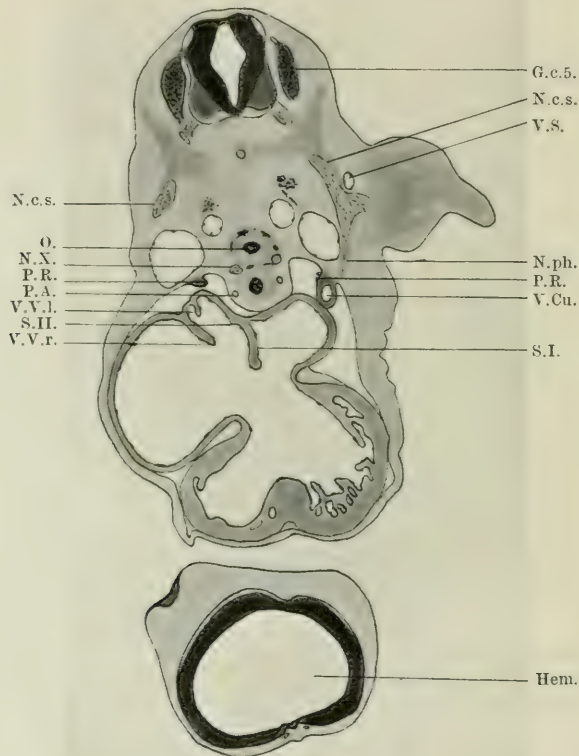


FIG. 9.  $\times 20$ .

densed mesenchyme with large nuclei, many of which are spindle-shaped, arranged concentrically in layers. This mesenchymal condensation is best marked below at the level of the bifurcation of the trachea, being absent at its upper end, and constitutes the circular oesophageal pre-muscle mass. It is covered externally by a continuous nerve-plexus layer, already described as composed of small masses of sympathetic tissue and branches from both vagus nerves (figs. 7-10).

The torsion of the stomach is not yet complete (*cf.* figs. 13, 15, 16, and 17). The widely expanded fundus is blown out to the left, and the organ as a whole is arched out well to the left of the plane of the middle line, while the pylorus and beginning of the duodenum are situated in that plane. The concentric "pre-muscle" arrangement of the investing mesoderm, seen in the lower end of the oesophagus, ceases at the cardia. In the root of the mesentery in this region are clumps of syncytial sympathetic tissue, and similar but smaller ganglionic masses are scattered dorsal to and to the right of the cardiac end of the stomach. No connexions with the sympathetic or vagal fibres are to be observed. The

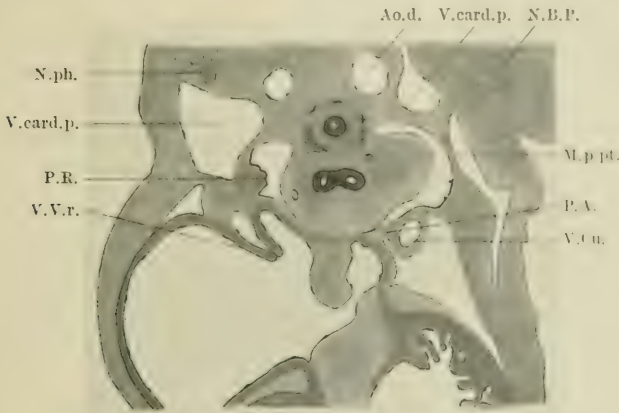


FIG. 10.  $\times 25$ .

blood-vessels of the stomach are represented by the a. gastrica sinistra, the splenic plexus (*cf.* below), and the small vein which runs from the fundus through the lesser omentum to join the ductus Arantii.

The duodenum has a patent lumen throughout. The intestinal tube from the pylorus to the apex of the intestinal loop runs somewhat to the right of the plane of the middle line (fig. 19). The intestinal loop has undergone a torsion of about  $110^\circ$ , so that the distal limb lies well oral in respect to the proximal limb (figs. A and 19). The apex is situated in a funnel-shaped pouch of the coelom in the base of the umbilical cord. A short distance proximal to this point the already slender intestinal tube becomes still further reduced in diameter, less sharply defined against the surrounding mesoderm, and loses its lumen through four sections (in position marked + in fig. A). The vitello-intestinal duct has separated, but remains of that structure appear in three distinct places in the sections.

in each case through a few sections only, as a slender column of degenerating cells lying free in the coelom of the cord and surrounded by an aggregation of blood cells representing the extravasated blood of the omphalo-mesenteric artery (*cf.* fig. 17). The distal limb of the loop increases greatly in diameter from the apex to a short distance beyond the caecum, beyond which it narrows again and is continued caudally in the middle line as large intestine and rectum. The connexion between the latter and the rest of the cloaca—"cloacal duct" of Reichel—is narrowed dorso-ventrally by an extensive development of the urorectal septum (figs. A and 20), and laterally by low broad vertical ridges of

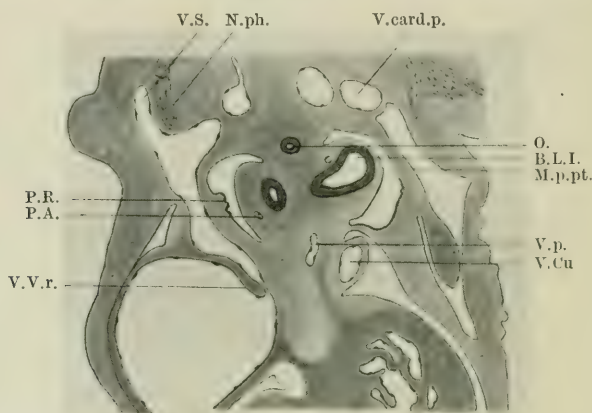


FIG. 11.  $\times 25$ .

mesoderm continued down from the lateral parts of the septum and swelling towards each other from either side. The duct is further constricted below by a transverse ridge from the inner face of the cloacal membrane, and has a dorso-ventral diameter of  $130\mu$ . A caudal intestine is present as a small blind finger-like pouch opening into the aboral part of the rectal cloaca and continued back as a solid cord of endothelial cells through nine sections ( $10\mu$ ). Further caudally and in line with this column a small interrupted epithelial "rest" appears (fig. A). The allantois comes off the anterior pole of the cloaca at a sharp angle, as is seen in fig. A, the transition from the latter organ to the former being a sudden one and not a gradual merging of one into the other (fig. 20). At first the allantois consists of a tube of small calibre which enters the root of the body-stalk and gradually insinuates itself between the umbilical arteries (figs. 20, 19, and 17). In this position it soon expands into a dorso-ventrally flattened

vesicle (fig. 17), and later, still increasing in calibre, it assumes a roughly circular outline in cross-section. In the distal part of the cord it branches so that in several sections a group of two, three, or more allantoic vesicles is to be seen. The allantois is lined throughout by a single layer of cells: at its origin from the cloaca and in its early tubular portion in the base of the body-stalk the cells are cubical, with pale protoplasmic cell bodies and rounded nuclei; more distally, where the tube expands and becomes vesicular, the cells become flattened and drawn out and the structure as a whole less sharply demarcated against the surrounding mesoderm.

#### LIVER, PANCREAS, SPLEEN, AND CÆCUM.

The entodermal liver tissue extends on the left side as the left coronary appendage dorsally and orally as far as the ventral pillar of the pleuro-

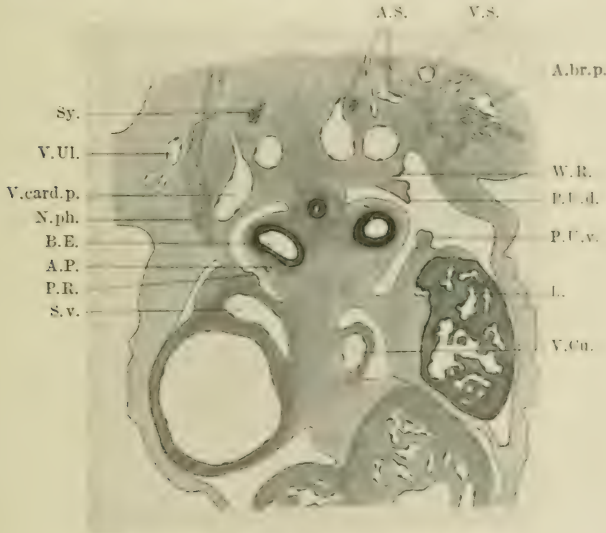


FIG. 12.  $\times 25$ .

peritoneal membrane, in the substance of the "pericardio-peritoneal membrane" (fig. 12). From the latter structure it bulges laterally into the antero-lateral recess and appears anteriorly in a few sections in a fold which is attached to the lateral aspect of the pleuro-peritoneal membrane (fig. 11). Caudo-ventrally it lies embedded in the substance of the mesoderm of the dorsal pericardial wall (septum transversum) and bulges into the peritoneal cavity, coming almost into contact with the lateral abdominal wall. Further ventrally, having joined the right lobe, it reaches and fuses



with the anterior abdominal wall caudal to the pericardium (compare figs. 12, 13, 15, and 16). Posteriorly the left lobe appears as a wing-like expansion of the right lobe (fig. 16), demarcated from the latter ventrally by the groove for the left umbilical vein, which here runs in the middle line to join the ductus Arantii. The right lobe, though exceeding the left in bulk, does not extend so far dorsally and orally; its coronary appendage is less marked and fails to reach the pleuro-peritoneal membrane (fig. 13). It extends, however, much further caudally,<sup>1</sup> frees itself from the dorsal

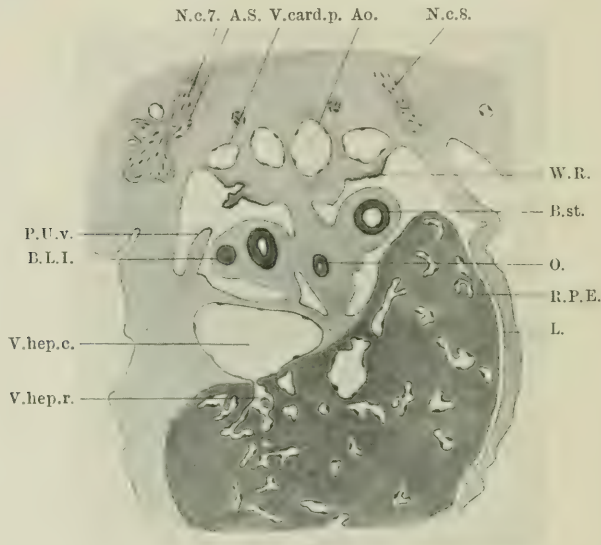


FIG. 13. × 25.

mesentery, and bounds orally and ventrally the peritoneal cleft which connects the bursa omentalis with the greater peritoneal cavity—the hiatus communis recessuum or future foramen epiploicum (*cf.* fig. 17 and below). The gall-bladder (Plate II. fig. 5) lies in a deep wide groove of the liver, filled with dense mesenchyme which separates it from the liver substance. Proximally the cystic duct becomes free from the liver, the mesoderm surrounding it causing a slight swelling under the peritoneum, and just before its junction with the hepatic duct a lumen appears within it. At this point the hepatic duct itself also acquires a lumen which is partially double. The common duct contains a lumen in its whole extent, and near

<sup>1</sup> Making every allowance and correction for the obliquity of the sectional plane, which has been done throughout.

its junction with the duodenum gives off the ventral pancreas anlage (Plate II. fig. 5, and fig. 18). The common duct at its origin from the duodenum is at first directed dorsally, to the right and orally. After giving off the ventral pancreas it twists on itself and runs orally ventrally and to the right, the cystic duct continuing this direction, while the hepatic duct takes an almost directly oral course (Plate II. fig. 5). The latter continues orally ventral to the omphalo-mesenteric vein (fig. 17) and soon becomes embedded in the liver, where its outline against the liver tissue proper becomes in many sections irregular and indistinct, the appearances suggesting the giving off of liver trabeculae. It can be traced, however, some distance in the substance of the liver as an irregular column of cells, smaller, darker, and more densely packed than the surrounding liver cells, until finally it loses its identity by merging gradually into normal liver tissue. The cells of the liver trabeculae consist of large polyhedral cells with dense granular protoplasm fitting close together and containing a large round, more lightly staining nucleus with usually two or three dark nucleoli. The endothelium of the numerous blood spaces closely invests the trabeculae, so that a perivascular space is seldom apparent. Typical "blood-forming" cells are absent, although a certain number of darkly staining cells, with little protoplasm and much smaller than the normal liver cell, occur scattered through the trabeculae and show a general resemblance to ordinary mesoderm cells. A few occur singly immediately beneath the endothelium.

*Pancreas.*—A wax model has been prepared of the dorsal and ventral pancreas anlagen, the hepatic ducts and a portion of the left lobe of the liver and omphalo-mesenteric vein. A drawing of the model is reproduced in Plate II. fig. 5. The ventral pancreas anlage is in the form of a lobulated sessile knob attached to the common bile duct close to its origin from the duodenum. The lobules contain wide-open longitudinally running lumina (fig. 18), with a general arrangement of one central lumen with a lateral lumen on either side. The central lumen opens into the bile duct, and its major portion is situated caudal to this communication. In the case of the lateral lumina no direct connexion either with the central lumen or with the bile duct could be made out, but the histological picture presented by the endothelial walls suggests an opening in both cases into the central lumen at its junction with the bile duct. Owing to the torsion of the proximal portion of the bile duct around the duodenum the ventral pancreas is directed dorsally and somewhat to the right and abuts against the vena omphalo-mesenterica, the wall of which it indents (fig. 18). It is separated from the proximal portion of the dorsal anlage only by a small interval. The dorsal pancreas springs from the duodenum

dorsally and to the left side immediately proximal to the entrance of the bile duct. It is lobulated like the ventral pancreas and is much larger, and lies in the dorsal mesogastrium with its long axis almost dorsoventral. The vena omphalo-mesenterica, in its spiral course dorsally and orally around the left aspect of the intestinal tube, is in close relation to the anlage grooving it on its right side and caudal face (Plate II. fig. 5, and fig. 18). In the latter position the groove is especially deep, owing mainly to the fact that a process of pancreatic tissue is continued caudally in the interval between the vein and the duodenum, lying close against the former (fig. 18). This process is separated from the duodenum by a deep notch. The anlage contains irregular lumina throughout, including the above-mentioned caudal process, in which one of the lumina is relatively large. The proximal portion of the lumen, or common duct, enters the duodenum in an obliquely oral direction, so that the latter appears in this position to have a double lumen through a few sections.

*Spleen.*—The anlage of the spleen is represented by a thickening of the coelomic epithelium over a relatively large area of the dorsal and lateral aspects of the left leaf of the dorsal mesogastrium, with proliferation of its elements (figs. 17 and 18). The thickening is best marked at the level of the origin of the dorsal pancreas, and results in the production of an epithelium several layers thick and consisting of a somewhat chromophobe protoplasm in which numbers of small round nuclei are set. It is demarcated from the underlying mesoderm by a layer of this lightly staining protoplasm with few nuclei. The area of the mesogastrium corresponding with the epithelial thickening projects from the surface and, where the proliferation is best marked, is notched on its coelomic aspect. The underlying mesoderm, which shows no special differentiation except for the presence of numerous mitotic figures, contains a plexus of blood-vessels which is connected on the one hand with the omphalo-mesenteric vein caudal to the dorsal pancreas, and on the other with the left gastric branch of the coeliac artery (*vide infra*).

*The Cecal Region.*—Fig. 6 on Plate II. is a drawing of a wax model of the apex and major portion of the intestinal loop, with a part of the superior mesenteric artery. On the distal limb of the loop a short distance from the apex is an ampullary swelling. From the lateral aspect of the ampulla springs a hollow diverticulum in the form of a short blunt cone directed orally and laterally. The diverticulum shows no distinction into basal and apical portions except in so far as its lumen may be divided into an ampullary section and a diverticular section proper. The ileum and colon are not quite in the same straight line, the latter being displaced somewhat laterally at its commencement relative to the former. This



relation of these two portions of the tube can be observed from the outer aspect, but is better marked as regards the lumen, so that the arrangement is best described thus:—the lumen of the colon followed orally divides as into the two limbs of a **Y**, one limb being continued into the ileum, the other ending blindly at the apex of the diverticulum. At the junction of the limbs of the **Y** the lumen undergoes enlargement. The ileum is thus inserted obliquely into the tube formed by the appendix and colon taken together. Immediately proximal to the appendix is a second smaller and solid epithelial appendage of the intestinal tube (Plate II, fig. 6). It has a similar direction as the former structure, *i.e.* orally along the ileum and laterally, and, though possessing no lumen, its cells, especially in its basal portion, are arranged regularly around a potential central cleft. Proximally it is partially embedded in the wall of the ileum, while its base winds round to the oral and dorsal aspect of the intestinal tube. The exact nature of this decidedly abnormal structure is not apparent. Its position with respect to the apex of the intestinal loop on the one hand, and the appendix on the other, would seem to rule out the possibility of its being a Meckel diverticulum, but it must be remembered that our knowledge of the growth relations of the various organs is very incomplete. The lack of accurate observations in this direction, and especially in the case of the alimentary canal, has been recently emphasised by the work of von Berenberg-Gossler, who proves conclusively that the whole of the rectum and colon as far as the cæcum must arise from the cloaca. In the present case the only safe criterion—namely, the relation of the structure to associated blood-vessels—is impossible of application, so that the question is incapable of definite solution. Another possible interpretation of the abnormality is that it is of the nature of those intestinal diverticula which have been described in the literature as occurring not only in the neighbourhood of the hepatic outgrowth but along the whole length of the ileum, and which have been generally regarded as pancreatic in nature. In this connexion it is interesting to note the observation of Wright, who finds an accessory pancreas in Meckel's diverticulum near the umbilicus.

#### HEART AND BLOOD-VESSELS.

The sinus venosus receives the two ducts of Cuvier and the v. hepatica revehens communis. Its slit-like opening into the atrium is bounded by two well-developed venous valves. The left valve passes below towards the left to end near the distal extremity of the dorsal prolongation of septum I. Orally it fuses with the right venous valve to form the venous septum (septum spurium). A few sections cephalad from the point of fusion of the two valves a septum detaches itself from the left aspect of



the venous septum near its base, and, rapidly increasing in height, passes obliquely over the posterior wall of the spatium septo-valvulare to end near the small septum II. This part of its course is marked on the outer surface of the heart by a distinct groove (fig. 9). This septum would seem to be a continuation of the left valve, as though the latter had again parted company with the venous septum, but that it is in reality of such a nature cannot be definitely stated owing to the complete fusion of the two valves immediately below. Septum I. is well developed (fig. 9), its

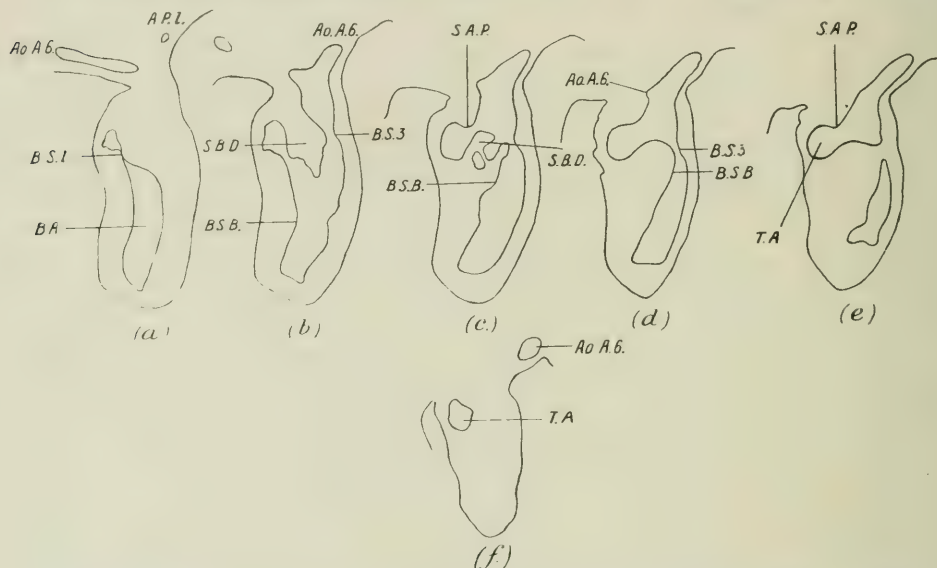


FIG. 14.—Tracings of six sections through the bulbus arteriosus. (a) Section 333 ; (b) section 329 ; (c) section 325 ; (d) section 321 ; (e) section 318 ; (f) section 313.  $\times 25$ .

free border being thickened and covered by a thickened endocardium. Its dorsal and ventral prolongations can scarcely be said to actually reach the endocardial cushions of the auricular canal; the dorsal one approaches its associated cushion very closely, but the ventral horn fades away into the ventral wall of the atrium before reaching the ventral cushion. The attached base of the septum shows two small perforations—an early foramen ovale II. A commencing septum II. is present as a short low ridge of myocardium to the right of the upper part of septum I. (fig. 9). The interventricular septum is still low. In the bulbus arteriosus proximal and distal bulbar swellings are well marked, and by their union with one another have brought about a partial separation of the bulbus into truncus aorticus and truncus pulmonalis. In fig. 14 are reproduced

tracings of six sections at various levels through the bulbus which exhibit the main features of the process at this stage. The proximal bulbar swellings A and B (Tandler) have the classical arrangement, the former beginning on the anterior wall of the bulbar portion of the ventricle and running distally on to the posterior wall of the bulbus, the latter passing from the posterior wall proximally to the anterior wall distally. Of the distal bulbar swellings described by Tandler in his model of the bulbus of the embryo  $H_6$ , and numbered 1 to 4, two, viz. 1 and 3, can be identified in the sections, and have produced the distal bulbar septum by uniting across the bulbar lumen, dividing it at this point into pulmonary and aortic constituents. The bulbar swelling A reaches the distal bulbar swelling 1 (fig. 14*c*), while swelling B fuses with swelling 3—that is, with the anterior pillar of the distal bulbar septum. Further, a blunt wedge of mesoderm juts into the bulbar lumen from an oral and dorsal aspect, so that both sixth aortic arches arise by a short common stem (figs. 7 and 14). This structure, the septum aortico-pulmonale, reaches the distal bulbar septum only through its dorsal and ventral prolongations, leaving between the edges of the two septa a foramen of communication between the aortic and pulmonary trunci.

Three complete aortic arches are present (fig. B). A pulmonary artery arises on each side from the sixth arch near its ventral origin. Each lies at first ventro-lateral to the trachea, passing dorsally later, the left before the right. The latter vessel runs caudally ventral to the apical (eparterial) bronchus bud (*vide* Lung, and fig. 12) and then dorsal to the first ventral bud, as His has shown for a 10.5-mm. human embryo, and Flint for the pig. The left artery passes back dorsal to the first ventral bud of the right side, and both arteries end by breaking up into a capillary plexus on the dorsal aspect of the flask-shaped extremity of the stem bronchus.

Into the lateral aspect of the dorsal extremity of the sixth arch on the left side opens a very small vessel, which can, however, be followed through a few sections. This stump is in the position of the original dorsal termination of the fifth arch, and corresponds with the findings of various observers, viz. Elze in a 7-mm. embryo. There can be little doubt that this structure represents the extreme phase of the involution of this vessel.

The truncus arteriosus bifurcates anteriorly into the third aortic arches. From the commencement of the third arch on either side a small vessel runs forwards beneath the pharynx—the external carotid. It becomes lost at the level of the first cleft and cannot be followed into the first visceral arch. The only definite branch which it gives off is one passing outwards and downwards as the second arch—the a. lingualis. There is, however, also in the arch a short upwardly directed vessel which might

perhaps be regarded as the ventral end of the second aortic arch. From the dorsal extremity of the third arch the dorsal aorta passes forward as the internal carotid artery. Immediately behind the level of the otic vesicle it gives off a comparatively large branch which is directed back-

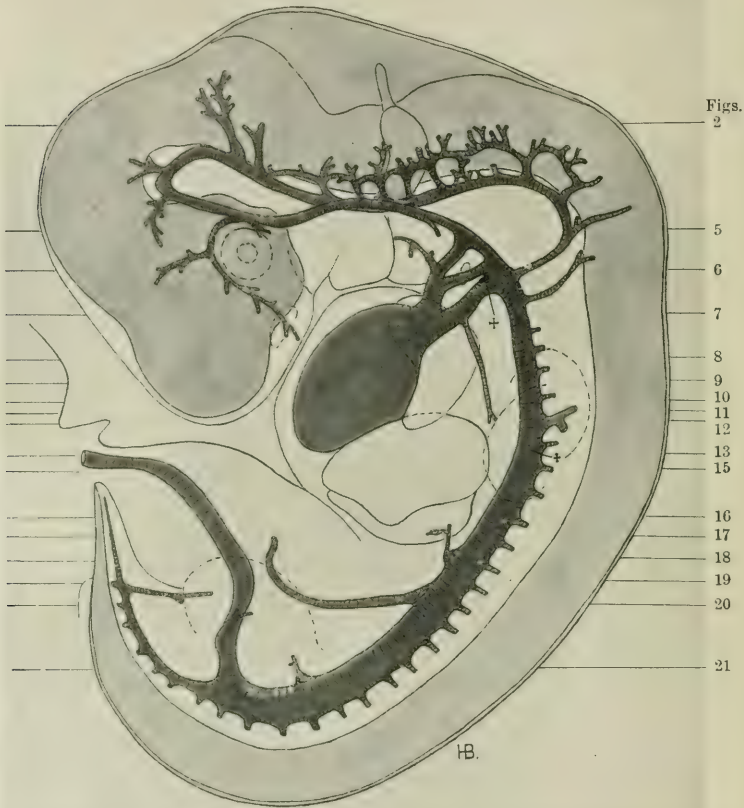


FIG. B.  $\times 12\frac{1}{2}$ .

wards and downwards into the second visceral arch. On the right side this vessel terminates by dividing into two branches, both directed ventrally. This vessel must be identified as the dorsal part of the second arch, or, after Tandler, the root of the stapedia artery. The a. carotis arches past the hypophysis, and as it passes over the optic cup it gives off a small ophthalmic branch. This vessel on the left side soon divides into two



branches, one of which can be traced to a capillary plexus on the upper pole of the retinal anlage. On the right side, where the artery is in a less contracted condition and the plane of section at the same time more favourable, the ophthalmic artery can be seen to pass out laterally over the optic cup and to connect with a plexus surrounding the edge of the cup and especially its temporal rim. This plexus is connected below with the anlage of the a. hyaloidea through a relatively large branch which passes out through the distal end of the chorioid fissure (*vide* Eye). The a. hyaloidea itself is represented by a large sinus-like and plexiform vessel lying in the anterior part of the chorioid fissure and projecting into the antrum cupulæ so as to abut against the lens vesicle. Traced proximally, the artery, besides connecting with a capillary plexus lying along the caudo-temporal aspect of the pedicle, is found to give off a short, stout branch which passes dorsally around the caudo-temporal aspect of the pedicle at the "insertion" of the latter into the cup. It is questionable whether this vessel represents the true proximal continuation of the a. hyaloidea or, as would seem more probable from the observations of Dedekind, Versari, and Fuchs on later stages, the a. ciliaris nasalis. The connexion of the a. hyaloidea with the ophthalmic branch of the a. carotis is thus a very indirect one. A similar independence of this artery is noted by Dedekind (6 mm.) and by Elze (7 mm.), and the condition receives an explanation in the findings of Fuchs in the rabbit, in which mammal he derives the a. hyaloidea from a marginal vessel encircling the edge of the optic cup.

After giving off the ophthalmic artery, the carotid—to follow the interpretation of de Vriese—divides into an anterior and a posterior branch. The former sweeps round the optic anlage, giving off to the side of the fore-brain the anterior chorioid artery, as described by Mall for 9 mm., and continuing ventrally internal to the nasal pit it breaks up into a capillary plexus over the ventral surface of the fore-brain. Through the plexus there is probably an anastomosis between the arteries of either side. As the artery passes internal to the olfactory epithelium it gives it a branch (fig. 8) seen on both sides. The posterior terminal branch of the carotid curves dorsally and backwards beneath the mid-brain and unites with its fellow (in position marked + in fig. B) to form the a. basilaris, but before doing so it gives off two strong branches to the floor and sides of the mid-brain. The latter together constitute the posterior cerebral group (Mall).

The arteria vertebralis cervicalis arises as the first cervical dorsal segmental artery opposite the dorsal extremity of the sixth aortic arch. It gives branches to the medullary tube identical with those of the



segmental arteries generally (*vide infra*), but continues forward ventrolateral to the hind-brain to unite with its fellow (in position  $\times$  in fig. B) to form the basilar artery. From the vertebral and basilar arteries numerous strong twigs ascend on the side wall of the hind-brain, many passing between the individual rootlets of N. XII. The most marked member of the series supplies the area immediately behind the isthmus, *i.e.* the cerebellar region. These vessels are united with one another by an irregular longitudinal anastomosis.

The roots of the dorsal aorta unite at the level of the 8th cervical segment (fig. B, +). At the level of the 5th lumbar segment, after giving off the aa. umbilicales, it is continued as the caudal aorta to the caudal tip. In several parts of its course the latter appears as two vessels of varying relative calibre, and at more than one level assumes a plexiform arrangement with "Inselbildung," so that the aorta appears at these points in the sections as three or more small vessels grouped together. Even where a single vessel is present it often shows strands of mesoderm traversing its lumen, so that we have here a well-marked instance of "several paths being used by the arterial blood before the reduction to a single vessel" (Evans).

Thirty-two dorsal segmental arteries are present, viz. twenty-five from the aorta proper and seven from the caudal aorta. Distally to the last of the caudal segmentals a few fine capillary vessels are directed dorsally towards the neural tube. In the more anterior members of the series all the principal branches of supply to the spinal cord have been laid down. Each artery runs through the mesodermal intervertebral foramen in company with the vein and anterior to the corresponding nerve, and at the level of the junction of anterior and posterior spinal nerve roots divides into three main branches: (*a*) towards the mid-ventral line of the cord—a. radicularis ventralis (figs. 5 and 15); (*b*) a branch passing between the dorsal ganglia and the wall of the neural tube and extending as far dorsally as the point of entry of the dorsal roots—the a. radicularis dorsalis (fig. 15); and (*c*) a branch directed laterally towards the myotome. The a. radicularis ventralis when it reaches the lateral edge of the Bodenplatte penetrates the substance of the tube, as the a. centralis, and passes dorsally between the differentiating anterior horn anlage and the undifferentiated radial layer (*vide* Spinal Cord), helping to demarcate the two areas (fig. 3). Between the individual aa. rad. vent. as they turn into the spinal cord a longitudinal anastomosis forms the primitive anterior spinal artery. The a. radicularis dorsalis can in many cases be seen to give a branch into the neural tube at the level of the dorsal extremity of the anterior horn. The branch (*c*) is present only in the case of the most anterior members of the series, viz. the first segmental on the right side, which sends a large vessel laterally

against the myotome. From the latter small branches are continued through the myotome accompanied by venous vessels, while to the outer side of the myotome numerous fine capillaries appear. We may thus speak of a penetrating "ramus cutaneus dorsalis medialis" (Evans).<sup>1</sup> There is no traceable longitudinal anastomosis between the cervical dorsal segmen-

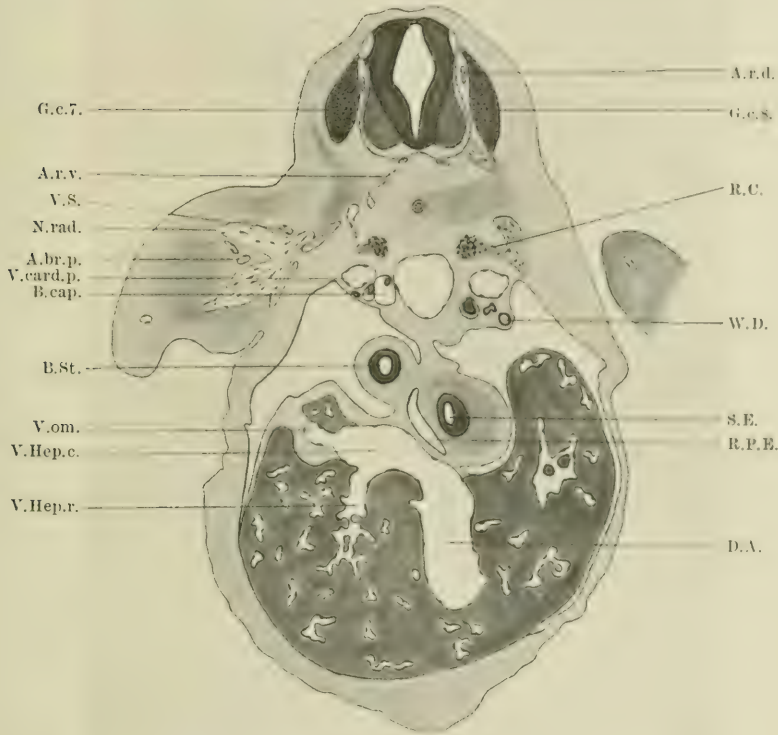


FIG. 15.  $\times 25$ .

tals to indicate a cervical vertebral system. The first three arteries, however, show a remarkable diminution in their lumina as they approach the aorta, so that at their origins they are little more than capillary in size. As we go caudally the proximal portions of these vessels increase in importance, and this fact, taken in conjunction with the well-developed condi-

<sup>1</sup> The a. rad. dorsalis from the 1st right dorsal segmental passes dorsally *external* to the ganglion, an arrangement which appears quite exceptional.

tion of the spinal branches of the most anterior members, must be regarded as indicating an involution of the aortic roots of these latter vessels.

*Ventral Branches of the Aorta.*—The coeliac artery springs from the aorta by two roots opposite the 5th thoracic dorsal segmental. From the loop between the two roots a small vessel passes ventrally and orally into the left leaf of the dorsal mesogastrium—a gastrica sinistra—and connects at the level of the pylorus with a relatively large plexiform vessel lying in the mesoderm beneath the splenic anlage—a. lienalis (fig. 17). This plexus, as has already been mentioned (*vide* Spleen), drains into the v. omphalo-mesenterica caudal to the dorsal pancreas (fig. 18).

The superior mesenteric artery arises opposite the 7th and 8th thoracic dorsal segmentals by a smaller anterior and a larger posterior root. It runs into the mesentery to the left of the intestinal tube and between the two limbs of the intestinal loop towards the caudally directed (originally right) face of the mesentery (Plate II. fig. 6, and figs. 19 and 20). It then passes towards the right across the caudal aspect of the proximal limb of the loop. As it reaches the surface of the mesentery it still possesses a relatively large calibre, but at this point the wall of the artery has been torn in the narrow interval between the mesentery and the lateral coelomic epithelium of the cord so that it cannot be followed distal to this point as a distinct vessel. There is, however, a continuous "clot" of blood cells traceable through about sixty sections and contained in a gutter of parietal coelom without any definite wall (fig. 17). That this collection of cells can be identified as the extra-embryonic portion of the artery is more than doubtful, and it is more probable that it is the result of a tearing of the vessel and an outpouring of its blood as the result of interference with the cord before fixing. It is, however, significant that the remains of the vitello-intestinal duct is found among these cells. The inferior mesenteric artery is small, and arises opposite the 2nd lumbar dorsal segmental by two main roots somewhat confused by "Inselbildung." It runs through about fifteen sections ( $10\mu$ ) before becoming lost in a capillary plexus. It gives a Wolffian branch to the mesonephros (*vide infra*).

The umbilical arteries arise in the 5th lumbar segment and encircle the posterior end of the coelom lateral to the Wolffian duct as the latter runs in the caudal end of the Wolffian mesentery. A short distance from its origin (fig. B) each artery gives off from its posterior aspect the a. ischiadica, which possesses a smaller and a larger root and runs distally and laterally between the teeth of the serrated edge of the hind-limb nerve-plate to break up into a large indefinite plexus. The two aa. umbilicales then approach each other at the root of the body stalk, the allantois inserting itself gradually between them (figs. 20, 19, and 17), a position which it



maintains in its course through the cord. Near the distal end of the latter the two arteries anastomose and after a short course as a single vessel separate again into two. The lumen of each artery is larger in the distal than the proximal part of its course.

From the ventral aspect of the caudal aorta between the last two dorsal segmentals a comparatively large branch runs on either side of the cloaca, just proximal to the cloacal membrane, and into the area oral and ventral to the urogenital section of the cloaca, *i.e.* in the angle between it and the allantois (figs. A and B). This area is drained by a venous plexus forming an anastomosis between the two umbilical veins (*cf.*). Elze describes this arterial branch in an embryo of 7 mm. (*circa*) as running "zur lateralen Seite des Enddarmes an dessen Übergang in die Kloake," but fails to find it in embryos of 9.5 mm. and 11 mm. The vessel in question would therefore appear to undergo rapid development and equally rapid involution.

*Wolffian Arteries.*—On the left side eighteen Wolffian arteries spring from the lateral aspect of the aorta: on the right side nineteen arteries come from the same source and one from the inferior mesenteric artery. They arise irregularly and show no segmental arrangement, the 6th and 7th on the left side for instance arising by a short common stem, while many, particularly in the case of the more caudal members of the series, divide in their distal course into two and supply adjacent glomeruli (fig. 21). The most anterior artery on the right side shows no apparent lumen, appearing merely as a cord of cells, while the second has a definite lumen only at its entrance into the glomerulus. The appearances provided by these arteries are probably associated with the degeneration of the corresponding Wolffian tubules, which cannot, however, be definitely diagnosed in the tubules themselves. As it enters the glomerulus each Wolffian artery shows a localised increase in calibre. The more anterior vessels are in very close relation to the dorsal aspect of the anlage of the suprarenal cortex.

The subclavian artery arches dorsally and laterally from its origin from the 7th dorsal segmental artery.<sup>1</sup> It perforates the base of the nerve-plate between C. VI. and C. VII nerves without previously giving off any branches. Appearing between the dorsal and ventral leaves of the plate, it continues for some distance as a definitely single large vessel on the dorso-lateral aspect of the ventral leaf—the "a. brachialis profunda" of Erik Müller (figs. 12 and 15). It gives off a branch which is directed along the radial nerve and rapidly becomes plexiform. The profunda trunk itself then shows island formation without the production of a definite

<sup>1</sup> The system of reckoning the dorsal segmental arteries here employed is that of Mall, Tandler, Broman, and Evans. Hochstetter, for instance, describes the arteria subclavia as arising from the *sixth* dorsal segmental. See footnote, p. 605 of Keibel and Mall's *Text-book*.



plexus, the lumen of the vessel being crossed by strands of mesoderm, while numerous short sprouts are given off from it. The vessel then divides into two, one branch continuing along the median nerve, the other along the ulnar, and each remaining as a single trunk for a short distance before appearing in the form of a plexus. The former is the larger of the two and constitutes the main continuation of the arterial trunk. Before penetrating the brachial plexus the subclavian artery gives off a branch which remains on the medial aspect of the ventral nerve-plate and shows a plexiform arrangement at its origin. From the latter point this vessel sends a small but definite branch medially and ventrally towards the pleura (internal mammary?), and continues ventro-caudally as a single trunk—"a. brachialis superficialis" of Müller—medial to the ventral nerve-plate and rami pectorales (fig. 15, right side), to end by turning laterally around the caudal edge of the plate to join the artery accompanying the ulnar nerve. On the left side a complete anastomosis between these two vessels cannot be traced owing to the fact that the artery accompanying the ulnar nerve is smaller on this side than on the right and breaks up earlier into a capillary plexus. Furthermore, the picture is somewhat obscured at this point by small folds in the root of the limb. The a. brachialis superficialis gives off in the same position on both sides, *i.e.* opposite C. VII. nerve, a small branch which pierces the base of the nerve-plate in a dorsal direction. On the left side this vessel ends beside the subclavian vein on the dorsal aspect of the plate.

*The Veins* (fig. C).—The anterior cardinal sinus begins anterior to the Gasserian ganglion as the v. capitis medialis, and is formed by the flowing together of two venous plexuses, one draining the side of the fore-brain and lying dorsal to the optic anlage, the other gathering its radicles from the mid-brain and isthmus region. According to Mall, these two plexuses together constitute the anterior cerebral vein. Both plexuses reach the mid-dorsal line, and form here a more or less definite longitudinal system. Especially is this the case dorsal to the cerebral vesicles, where a fine venous vessel is present on either side of the middle line—the sinus sagittalis (fig. 8). More posteriorly the arrangement becomes less regular. Receiving several smaller tributaries, the v. capitis passes back internal to ganglion N. V. and here receives a large branch from the maxillary arch beneath the optic cup. The latter before its junction with the main trunk is joined by a vein coming from the hypophysis. Closely applied to the lateral surface of the ganglion is a capillary venous plexus in connexion anteriorly and posteriorly with the v. capitis, providing a basis for the later-formed external venous ring. Immediately caudal to the ganglion the vein—now the v. capitis lateralis—gets a double tributary from the

anterior part of the hind-brain (middle cerebral vein, Mall), from which point it runs caudally external to N. VII. and N. VIII., the otic vesicle and N. IX. getting small branches from the first and second visceral arches on its course. Between N. IX and N. X. the posterior cerebral vein enters it



FIG. C.  $\times 12\frac{1}{2}$ .

in the form of a large vessel from the posterior part of the hind-brain, and immediately posteriorly is a smaller branch belonging to the same system. The v. cardinalis anterior then sweeps round the vago-accessory trunk altogether lateral to it, but quickly getting on to its dorsal aspect and separating it from N. XII. It is crossed laterally by the accessory nerve, and lower down by the hypoglossus trunk and its cervical contributions.

Here the vein becomes much increased in calibre and comes to lie once more lateral to the vagus. A large venous plexus lying in the floor of the mouth drains back across the ventral ends of the visceral arches towards the lateral aspect of the vagus trunk—the linguo-facial vein (Lewis). No definite connexion with the v. cardinalis anterior could be made out on either side. As the latter lies dorsal to the auricle it gives off in the 5th cervical segment the duct of Cuvier, relatively longer with a smaller diameter on the left side, shorter and wider on the right. This vessel immediately enters the pleuro-pericardial membrane and sweeps ventro-laterally to enter the lateral horn of the sinus venosus (figs. 9–12). In the latter part of its course the v. cardinalis anterior receives several dorsal segmental tributaries. Opposite the duct of Cuvier, *i.e.* in the 5th cervical segment, it is joined by a large vein which drains the post-axial border of the limb, its tip, and the distal part of its pre-axial border—the brachio-ulnar trunk. As the primitive ulnar vein enters the body-wall from the post-axial part of the root of the limb it is joined by a vein which drains, through superficial tributaries, the lateral wall of the thorax caudal to the arm-bud—the thoraco-epigastric vein of Lewis. The trunk thus formed runs oralwards as the subclavian vein dorsal to the nerve-plate of the limb plexus (figs. 9, 12, 13, 15), hooks around the anterior end of the latter and the phrenic nerve, and is joined before its termination by a small vein from the proximal part of the pre-axial border of the limb.

The posterior cardinal sinus is formed at the level of the 1st sacral segment by the junction of the ischiadic vein from the post-axial border of the hind-limb bud and the relatively small caudal vein from the tip of the tail. The caudal veins remain separate (figs. 20 and 21), but are connected with each other through anastomoses in front of the caudal aorta. From this level the posterior cardinal vein runs oralwards, passing lateral to the origin of the umbilical artery and dorsal to the mesonephros, and receives the dorsal segmental veins. The subcardinal system, the extent of which is indicated in the reconstruction reproduced as fig. C, is present in a well-developed condition. The v. cardinalis posterior as it runs dorsal to the Wolffian body receives two sets of tributaries, a mesial and a lateral. The former are the larger and are best marked in the lower dorsal and lumbar segments, where they anastomose to form a definite longitudinal vessel, lying internal to the Wolffian body and on a plane well ventral to the posterior cardinal—the (medial) subcardinal vein (fig. 19). At the hinder end of the mesonephros this vein is in connexion with its parent posterior cardinal trunk by a large anastomotic vessel (fig. 21), present on both sides, similar to that modelled by Félix in a 9.5-mm. embryo (fig. 574, Keibel and Mall), and forming in his description the posterior termination of the



medial subcardinal. The latter vein is, however, in the embryo under description, continued caudally to this anastomosis internal to the umbilical artery at its origin and dorsal to the mesenchyme of the metanephros to join the posterior cardinal vein just oral to the junction of ischiadic and caudal veins. There are thus two definite channels by which the blood coming from the posterior end of the body can enter the subcardinal vein. In the upper dorsal segments the mesial Wolffian tributaries do not anastomose to form a longitudinal vessel, though many of them are T-shaped as described by Félix. The more anterior members of the series run through the anlage of the suprarenal cortex and take over the drainage of this structure (fig. 18). This anterior disconnected portion of the subcardinal system is further related on the right side to the posterior extremity of the developing anlage of the inferior vena cava, to be later described. The lateral Wolffian tributaries drain dorsally between the individual collecting tubules of the mesonephros. They also unite to form a lateral anastomosing vessel, which, however, fades away behind. The medial and lateral vessels are united together by anastomoses, which can be seen passing between every two Bowman capsules, an arrangement which suggests a functioning mesonephric portal system at this stage. The subcardinal veins of either side have no connexion with each other across the front of the aorta. Of the *venae umbilicales* the left is very large, and entering the body-wall from the umbilical cord, it receives, besides superficial tributaries from the body-wall, a larger vein coming from a caudal direction. This vein is present also on the right side, and both commence in a plexus which forms an anastomosis between the two and lies in the angle between the antero-ventral surface of the cloaca and the allantois. This vein therefore drains the area supplied by the cloacal branch of the caudal artery, which has already been described in connexion with the latter vessel. Striking the anterior surface of the liver, it grooves the ventral surface of that organ for some distance (fig. 16) before joining with the *v. omphalo-mesenterica* ventro-lateral to the stomach. Before its termination it gives off a large *vena adhaerens* to the left lobe of the liver—*ramus angularis* (Mall)—and a smaller one to the right lobe. The *vena umbilicalis dextra* has reached an advanced stage of involution and has no longer an independent existence, opening at both ends into the left vein, viz. in the umbilical cord and again immediately before the left vein strikes the liver (fig. 17). Like the latter vein it receives numerous tributaries from the body-wall.

The peripheral portion of the degenerated vitelline vein is present as a blind stump projecting freely into the coelom ventral to the mesentery, and provided with a coating of mesoderm (fig. 19). Entering the mesentery it



encircles the intestinal tube on the left side, and as it winds round to get on to the dorsal surface of the latter it is joined at this point (*i.e.* in the position of the original dorsal or middle vitelline anastomosis) by the superior mesenteric vein (fig. 5, Plate II.). The latter begins in a few small radicles near the tip of the intestinal loop and runs in the mesentery, keeping on a plane to the left of the small intestine and duodenum.

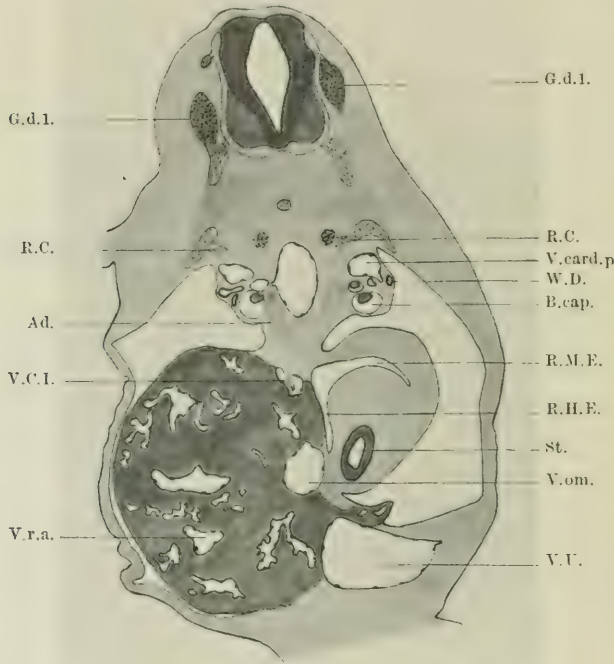


FIG. 16.  $\times 25$ .

The omphalo-mesenteric vein formed by the junction of the vitelline remnant and the superior mesenteric vein winds on to the dorsal aspect of the duodenum, grooves the under surface and mesial aspect of the dorsal pancreas anlage, and applies itself so closely to the now dorsally directed pancreas that its wall is indented by that structure (fig. 18). Continuing its spiral course, the vein plunges obliquely into the left face of the right lobe of the liver to the right of the stomach (Plate II. fig. 5), and joins the v. umbilicalis sinistra. Before its junction with the latter vein it gives off

into the right lobe of the liver a large vena advehens which immediately divides into two, one branch being directed ventrally—ramus arcuatus venæ portæ (figs. 17, 16)—and the other dorsally and constituting the

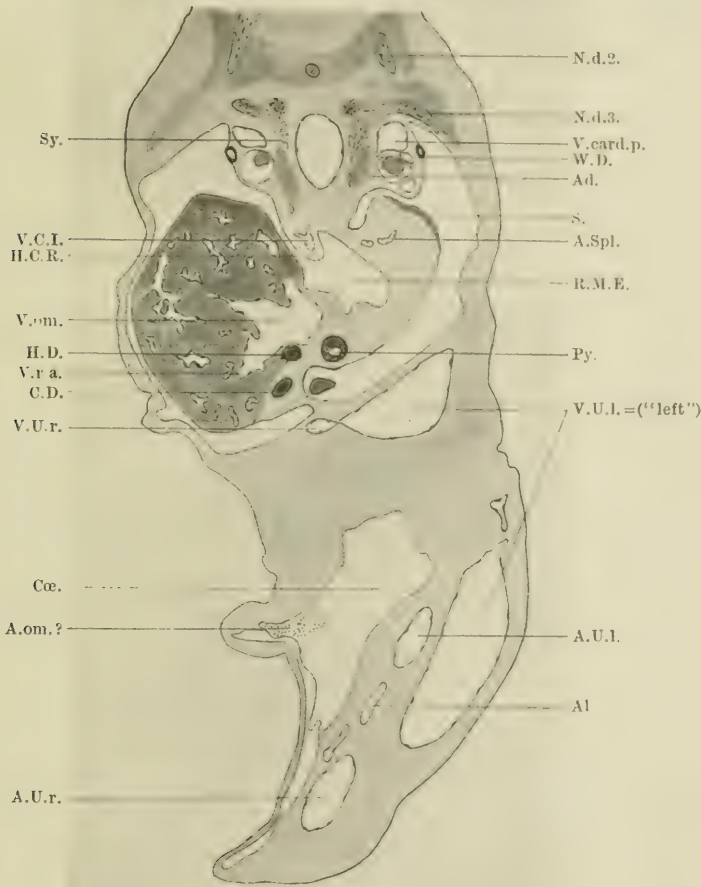


FIG. 17.  $\times 25$ .

continuation of the main omphalo-mesenteric trunk or right vitelline vein (Mall). From the junction of the v. umbilicalis sinistra and v. omphalo-mesenterica the wide ductus Arantii runs orally and dorsally through the liver (fig. 15), receiving at least one small tributary from the fundus of the stomach through the lesser omentum, as Broman described, to open into the

v. hepatica revehens communis or caudal prolongation of the sinus venosus from the left side. This latter receives also the common opening of the rami dextra and sinistra venæ hepaticæ on its anterior aspect and to the right of the opening of the ductus Arantii, and on its right side the persist-

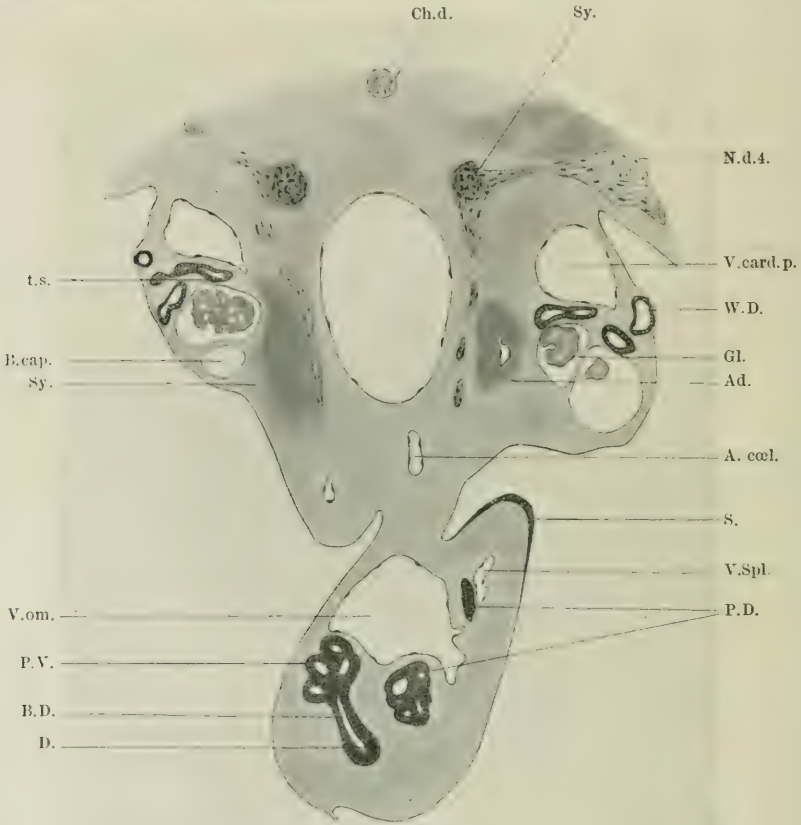


FIG. 18.  $\times 65$ .

ing terminal portion of the omphalo-mesenteric vein (fig. 15). The vena hepatica revehens communis is continued caudally into liver sinusoids lying in the dorsal margin of the liver, and through these is in connexion with a definite venous vessel which runs caudalwards in the border line between the liver tissue and the mesoderm bounding it dorsally, to the right of the recessus mesentericus and in the right leaf of the dorsal mesogastrium, *i.e.* in the caval mesentery. More posteriorly it leaves the dorsal surface of

the liver, passes dorsal to the hiatus communis recessuum and comes to lie ventro-mesial to the right mesonephros, and comes into relation with the anterior extension of the subcardinalis system, with which it is connected by anastomosis. We have therefore here present a definite anlage of the inferior vena cava (compare figs. 15-18). A single pulmonary vein opens into the caudal part of the atrium to the left of the lower end of septum I. It gets a large branch from the mesoderm in front of the left lung anlage and smaller tributaries from the right.

*Note on the Blood.*—On Plate II. fig. 7, *a*, *b*, and *c*, are pictured the main characters of three nucleated red blood cells from the spatium septo-valvulare of the heart. The nucleus shows a gradation in the density of its network—"ichthyoid" and "sauroid" types of Minot. The size of the nucleus in relation to the size of the cell-body diminishes from *a* to *c*, while the three cells show a varying depth of colour in their protoplasm. In general it may be stated that practically all the types of red cell are present which have been described by Maximow for mammalian embryos. His "primitive blood-cells" or the "primitive mesangloboids" of Minot could not be definitely identified. In *a* we have a typical "normoblast" of Maximow, and *c*, according to his interpretation, is a "primitive erythroblast," while *b*, in as far as the deep red coloration of its protoplasm is concerned, must be classed as a "megaloblast." Mitotic figures occur frequently in the nucleated red cells of the blood-stream. Non-nucleated plastids occur but sparingly in the embryonic vessels, but beneath the amnion in the distal part of the cord and in the "chorionic cavity," artificially produced by a stripping off of the amnion from the surface of the cord, numerous non-nucleated red cells are found in company with nucleated normo- and megaloblasts. These are much smaller than the embryonic blood cells proper and very irregular in shape, and have resulted probably from an extravasation of maternal blood from the placenta. Plate II. fig. 7, *d*, represents three leucocytes ("lymphocytes" of Minot) with typical reniform nuclei which contain numerous relatively large chromatin aggregations. The nuclei are basophile and stain blue in the sections. The protoplasm is clear, with a vacuolated appearance, and is non-granular. Such cells are relatively few in number and always occur in groups, in which however the cell boundaries are distinct. Schridde, in his paper on the development of the blood in early human embryos, asserts that up to a stage of 12 mm. no leucocytes are present in the blood-stream, being first formed in the liver when that organ enters on its blood-forming function. Maximow strongly opposes this view, and in the face of the present findings the position of Schridde would appear quite untenable.



## THE UROGENITAL SYSTEM.

The *Mesonephros* is situated between the 8th cervical and 3rd lumbar segments inclusive. On the left side thirty-seven tubules are present, all of which are S-shaped and provided with Bowman capsules and have collecting tubules opening into the primary excretory duct. On the right side occur thirty-eight complete tubules with capsules and collecting tubules opening into the duct, and posterior to these is a 39th and rudimentary member of the series. The latter is in the form of a small, more or less olive-shaped epithelial body, containing a lumen and with a solid pole abutting very obliquely against the mesial aspect of the Wolffian duct without opening into it. According to Félix, no new tubule anlagen are added at the caudal end after the 7-mm. stage; and since this tubule scarcely corresponds in its relations or appearance either with a normally developing or with a normally degenerating tubule, the structure in question is probably to be regarded rather as of an abortive nature. The more caudal tubules on both sides cannot be said to have completed their development, inasmuch as the capsules here consist of widely open saucer-like structures, in contrast to the double-sphere form with only a small aperture for the glomerular vessels seen in the more anterior members of the series. On the left side there are no definite signs of degeneration either cranially or caudally, except in the somewhat shrunken appearance of the more anterior glomeruli and their smaller size in relation to the comparatively large capsule. For the right side the same statement holds good with regard to the anterior tubules, but here there is further to be observed an involution of the two anterior Wolffian arteries. The first possesses no apparent lumen, consisting merely of a cord of cells connecting the capsule with the aorta, while in the case of the second no opening into the aorta could be made out. This negative finding may be due to a slight folding in this region, but the artery is nevertheless far from normal and its glomerular plexus less evident than those of its caudal neighbours. The primary excretory duct is anteriorly and on either side continuous at an angle with the first collecting tubule, and runs caudally close beneath the colomic epithelium lateral to the Wolffian tubules (figs. 15-21). At its caudal end it curves towards the middle line and runs internal to the origin of the umbilical arteries to end by opening into the dorso-lateral aspect of the urogenital cloaca (fig. A). At the junction of each collecting tubule the duct undergoes a localised enlargement (compare the two sides of fig. 18). Towards the caudal end of the mesonephros the enlargements run together, and the duct appears in consequence as a tube of much larger calibre. Caudal to the last mesonephric tubule it suddenly narrows,

and remains relatively small down to the point of origin of the ureteric outgrowth. Posterior to this point it expands into a funnel which is

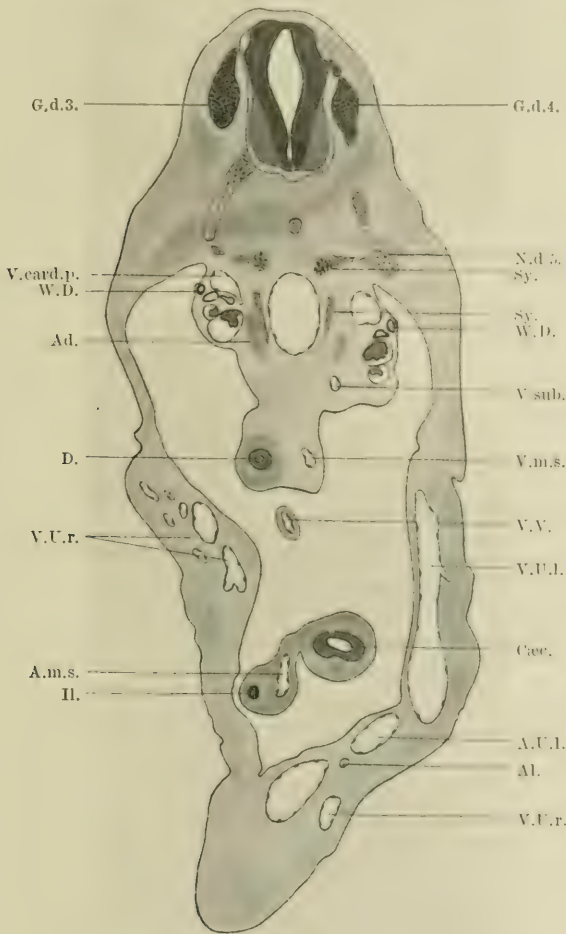


FIG. 19.  $\times 25$ .

still definitely marked off from the cloacal lumen. No pronephric rudiments are to be seen on either side. The vessels of the mesonephros have been fully described in the sections on the circulatory system.

*The Metanephros.*—The ureter arises from a somewhat lateral as well

as dorsal aspect of the primary excretory duct of the mesonephros a short distance from the opening of the latter into the cloaca (fig. A). The

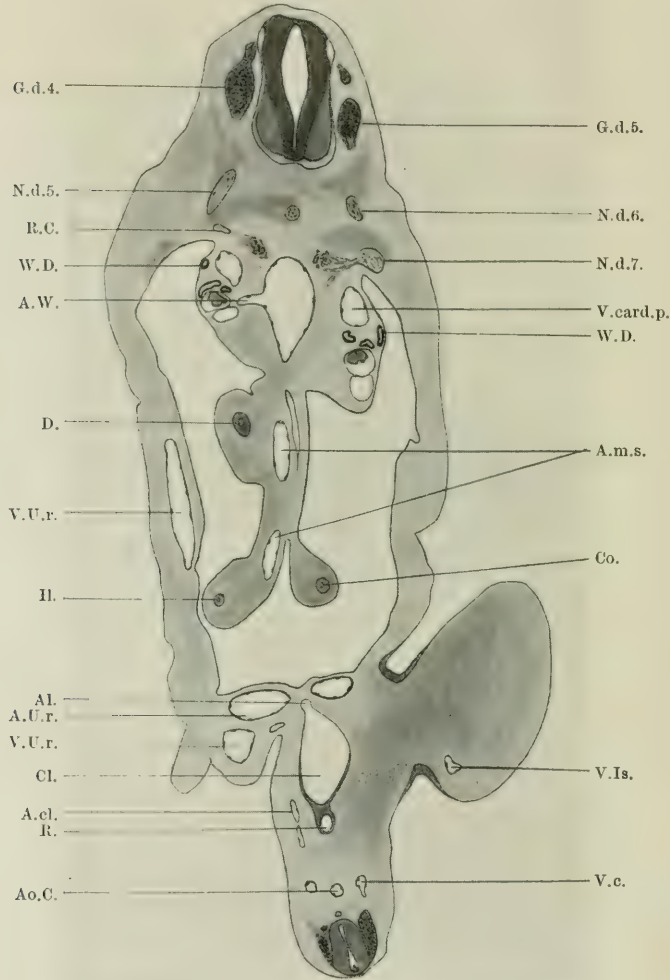


FIG. 20.  $\times 25$ .

renal pelvis is differentiated from the ureter proper and has the form of a flask-shaped terminal swelling slightly flattened laterally, the whole anlage being curved with its apex directed orally as well as dorsally (see fig. A).

The pelvis is capped by a layer of very dense mesodermal tissue in which the nuclei are arranged in a markedly radiating manner. From this cap a thick cord of condensed mesoderm stretches forward to a point caudo-

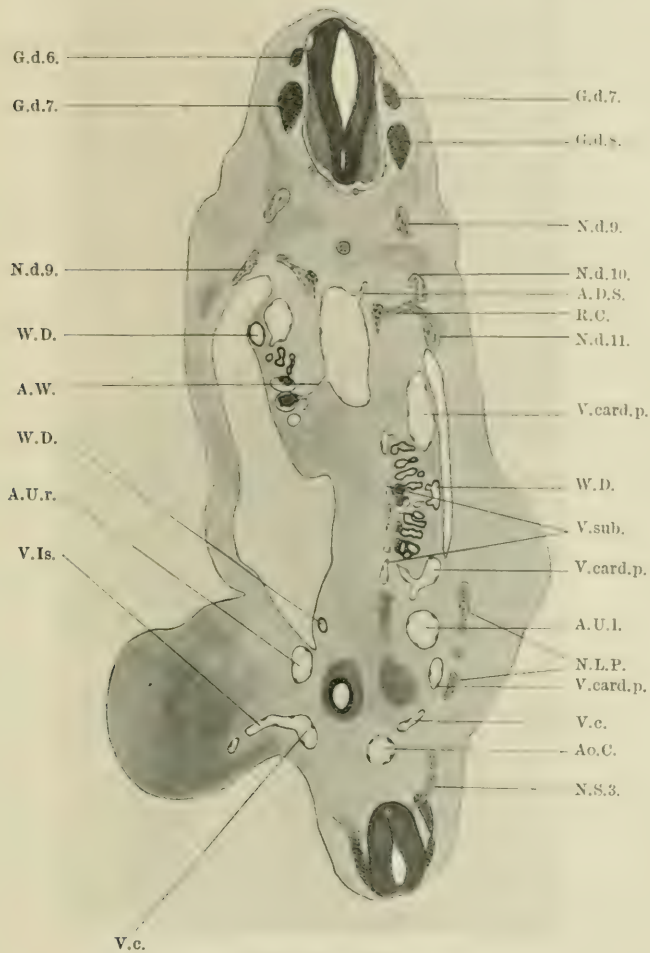


FIG. 21.  $\times 25$ .

mesial to the tail of the mesonephros and ends close to the latter, being separated from it only by the large anastomotic vessel which here connects the subcardinal with the posterior cardinal vein (fig. 21). The subcardinal is continued caudally dorsal to this condensation, as has already been mentioned in connexion with that vein.



## THE GENITAL EPITHELIUM AND "GENITAL CELLS."

A germinal epithelium exists only in a very early and indefinite condition. There is some thickening of the coelomic epithelium between the Wolffian ridge and the root of the mesentery in the lower dorsal region on either side, with some proliferation of its elements in a dorsal direction against the mesoderm. This thickening has no definite anterior or posterior boundaries, and passes gradually laterally and mesially into the unthickened area without any distinct line of demarcation. In connexion with the reproductive epithelium, however, mention may be made of a very characteristic type of cell found in the dorsal part of the mesentery and between this point and the germinal region at the lower dorsal levels. In Plate II, fig. 8, *a*, one of these cells is figured lying in the mesentery about midway between its base and the intestinal tube. Its large size and definite outline at once differentiate it from the surrounding mesoderm cells. The nucleus is regularly rounded and eccentric and contains a large irregular chromosome resulting from a clumping of the nuclear chromatin network (von Berenberg-Gossler), and divided into two portions, which, however, remain connected by a fine bridge. The cell-body contains a clear protoplasm with a generally vacuolated appearance, but in close contact with the nucleus and in the long axis of the cell is a close network—a more or less typical "Golgi-net"—containing a single dark spot, probably of the nature of a centrosome. In fig. 8, *b*, Plate II., a somewhat similar cell is shown, in which, however, the Golgi-net is absent and the chromosome in three portions. This cell was found between the Wolffian body and the root of the mesentery some distance dorsal to the coelomic epithelium. Fig. 8, *c*, is of a cell of the same type, but from amongst the cells of the proliferating genital epithelium. The cells here pictured, which occur only sparingly in the situations mentioned, closely resemble those which have for many years been described in the literature as "genital cells" for the various vertebrate classes, and their appearance at once suggests the possibility of their being of this nature. The origin of primitive "sex cells" from other sources than the coelomic germinal epithelium has long been an established fact, although observations in this direction on the human embryo have been very limited, and the question whether such cells are genetically continuous with the definitive genital cells has remained unsolved. Félix, recording the occurrence of "primary extra-regional genital cells" in human embryos of 2.5, 2.6, and 4.9 mm.—in the earlier stage in the neighbourhood of the cloaca, in the later stage in or under the coelomic epithelium near the root of the mesentery—states that in amniotes all the primary cells either disappear entirely or enter on

a latent stage with a possible later appearance as definitive secondary cells. Fuss (1912), on the other hand, in his work on the genital cells of man and mammals, traces the path of these cells from the entoderm of the yolk-sac to the genital region in later stages, and holds that inclusive of the human embryo the so-called "germinal epithelium" plays only a very unimportant rôle in the genesis of the sex-cells, and begins to proliferate only when the majority of the genital cells, coming originally from the yolk-sac entoderm, have arrived at their destination in the genital region. Von Berenberg-Gossler (1912) has further worked out and pictured the histogenesis of the primitive genital cells in the chick and embryo duck, and it is an interesting fact that the cell figured in our Plate II, fig. 8, *a*, is almost identical with those in his figures of three- to four-day embryos after staining with iron-hæmatoxylin. This author finds that cytological analysis provides no definite proof that these cells are in reality the ancestors of the male or female reproductive cells, and, with Fick, regards the peculiar clumping together of the nuclear chromatin as a "resting-network," associated with diminished functional activity. The suggestion that the appearance of such cells as those here described for the present embryo is due merely to an enlargement and modification of ordinary mesoderm cells in preparation for mitosis is at once disposed of by the striking analogy which exists between these cells, and those of the chick, in which mitotic division is absent or exceedingly rare. Furthermore, where mitotic division occurs in the surrounding mesoderm, as it frequently does, the cell in this case, although assuming a rounded-off appearance and increase in bulk, as described by Maximow, never simulates the cells in question either in size or histological character. That, finally, they are not to be identified as of the nature of "Wanderzellen" of Maximow is shown by the regular rounded nucleus which they in every case possess.

#### THE CONNECTIVE TISSUES.

The chorda dorsalis extends from a short distance behind the hypophysis (fig. 5) to the tip of the tail. It is in contact with the epithelium of the roof of the pharynx. On cross-section it shows a thick homogeneous membrane enclosing a clear, apparently homogeneous protoplasm in which the nuclei are arranged in a single circle in the middle thickness. No cartilage or "pre-cartilage" is present in the membranous skeleton. Parts of the base of the skull are indicated in membrane, viz. the pars petrosa, as well as the vertebral bodies with costal processes and a few ribs. The anlage of Meckel's cartilage has been mentioned above in connexion with the mandibular nerve. Three head segments and thirty-six or thirty-seven body segments are present. In all three of the former distinct differentiated

muscle fibres are to be observed, as is the case with the body segments as far caudal as the fourth sacral.

#### THE BODY-CAVITIES.

The lateral halves of the pericardium communicate with each other in front anterior and ventral to the truncus arteriosus. Soon, however (fig. 7), the two become separated by the mesoderm surrounding the truncus and bulbus, which extends from the dorsal to the ventral wall of the pericardium. Its dorsal attachment, or anterior section of the dorsal mesocardium, is little more than the mesoderm surrounding the truncus and sixth aortic arch as these leave the pericardial cavity. Ventrally the bulbus is closely applied to the anterior pericardial wall through about thirty sections ( $10\mu$ ), and partial fusion occurs (fig. 7). There is in every section, however, a broken line of epicardium demarcating the two, so that the fusion is very incomplete, and one cannot speak of a true ventral mesocardium in this region. Behind the point where the anterior section of the dorsal mesocardium ceases the broad tracheal ridge juts dorsally into the pericardium, and gradually increasing in dorso-ventral height it finally fuses, from the tracheal bifurcation caudally, with the dorsal surface of the heart to form the main or caudal section of the dorsal mesocardium (figs. 9 and 10). From this point the dorsal wall of the pericardium, with which the dorsal mesocardium is continuous on either side, slopes rapidly ventrally and caudally, and is here formed by the comparatively smooth antero-ventral surface of the septum transversum. On either side of the tracheal ridge ("bourrelet mésentérique" of Brachet) anteriorly is a broad groove without any definite lateral boundary (on left side of fig. 8). Traced backwards this groove gradually deepens and narrows ("gouttière pleuro-péricardique" of Brachet) and a well-marked ridge appears to demarcate it laterally (right side of fig. 8). More caudally still the groove becomes bounded on its lateral aspect and later ventrally also by the duct of Cuvier as it sweeps caudally and mesially, and by the mesodermal membrane which connects that vessel with the body-wall (fig. 9). The groove ("gouttière pleurale") is, however, still incomplete below, inasmuch as its appearance in the above figure as a closed "cavity" is due to the presence of a portion of the atrial wall, and it is only when the mesoderm on the dorsal and mesial aspect of the duct of Cuvier fuses with the dorsal mesocardium and thus completes the pleuro-pericardial membrane that the pleural cavity is fully shut off from the pericardium proper (fig. 10). Between the anterior and posterior sections of the dorsal mesocardium the pleuro-pericardial grooves communicate with each other, at first freely but more caudally through a slit-like space between heart and tracheal swelling. The part played by the duct of Cuvier in bounding the



pleuro-pericardial opening can be well seen in figs. 8 to 11. The duct with its mesodermal connexion with the body-wall bounds the groove at first laterally and then later below, but the ridge thus produced, as Brachet and others have pointed out, does not constitute the anlage of the pleuro-pericardial membrane proper. From the mesial aspect of the duct of Cuvier at its oral and dorsal end a prominent ridge, already mentioned, consisting of condensed mesoderm with thickened epithelium and an irregular surface, extends oralwards and gradually moves on to the dorsal aspect of the pericardium, reaching in front the lateral part of the "bourrelet mésentérique." This is the anterior extension of the pulmonary ridge (Mall). Behind, it spreads out, first on the mesial, later on the dorsal aspect of the Cuvierian duct, and adds itself to the mesodermal membrane, connecting the latter with the body-wall, while, as Brachet has shown, it joins the mesoderm around the duct, by its active growth, with the dorsal mesocardium, and through this with the mesodermal lung anlage (fig. 10). It thus converts the pleuro-pericardial groove into a "cavity," and is connected at both ends with the mesoderm surrounding the lung, and can later, by active growth, complete the closure of the pleuro-pericardial opening. The pulmonary ridge being thus the true anlage of the pleuro-pericardial membrane, the duct of Cuvier lies at first in its lateral edge and later comes to hang from its ventral surface (fig. 10). Still later it leaves the pleuro-pericardial membrane altogether (fig. 11) to run along the lateral aspect of the dorsal mesocardium before entering this structure on its way to the sinus venosus. In other words, the "lateral mesocardium" and the pleuro-pericardial membrane are two distinct structures, the former bringing about a constriction of the pleuro-pericardial communication without taking any active part in the actual closing process. In figs. 10 and 11 the antero-lateral recess of the peritoneal cœlom has appeared (on the right side of both figures), and here the pleuro-pericardial membrane forms a T-shaped junction with the pleuro-peritoneal membrane extending dorsally and the "pericardio-peritoneal membrane" ventrally and laterally. The latter is at no point a true membrane like the other two, being very much thicker, and constitutes in reality the anterior or dorsal edge of the septum transversum, in which, a few sections posteriorly (fig. 12), liver trabeculae appear. It is thus seen that the pleuro-pericardial membrane is itself a portion of the anterior edge of the septum. In fig. 11 the dorsal attachment of the pleuro-peritoneal membrane is the dorsal body-wall under the cardinal sinus; ventrally and mesially it is continuous with the dorsal surface of the septum transversum, through the pleuro-pericardial and "pericardio-peritoneal" membranes. It has spread out on its mesial surface the epithelium of the pulmonary ridge, and is partly made up of that structure.



Followed forward it is seen to be attached to the posterior aspect of the dorsal part of the duct of Cuvier (Brachet), as well as being continued orally from that level and mesially as the pulmonary ridge. Posteriorly it ends in a caudally directed free edge with dorsal and ventral prolongations which differ somewhat on the two sides. On the left side the dorsal prolongation, or dorsal pillar of Uskow, is the better marked, is continued into a ridge mesial to the anterior extremity of the Wolffian mesentery (fig. 12), and gradually fades away in this position. The ventral pillar is thicker and flattens out rapidly into the septum transversum, or, more correctly, is invaded and spread out by liver tissue so that it soon loses its ridge-like form. On the right side, where the right lobe of the liver has not reached the ventral pillar, the latter is high and sharp (fig. 13) and is continued back along the upper surface of the septum transversum. In general the pleuro-peritoneal membrane is situated in a sagittal plane, but is bulged laterally by the mesodermal lung anlage.

When the condition described above is compared, for instance, with that found in a 7-mm. embryo, in which, as Mall says, the pulmonary ridge "connects the dorsal end of the septum transversum with the Wolffian body," as is seen in the large Piper-Ziegler model of a 6.8-mm. embryo (1902): and when it is further considered that this ridge is the anlage of both pleuro-pericardial and pleuro-peritoneal membranes, it is possible to appreciate the full significance of Brachet's description (1897) in which he regards both anlagen as "spreading so to speak from one point to develop in different directions, one caudal and the other cranial."

The liver bulges from the dorsal surface of the septum transversum, reaching farther forward on the left side, where it ends in a wing-like expansion extending into the antero-lateral recess (fig. 11). On the right side, though not extending so far forward, it fills up most of the anterior portion of the greater peritoneal sac. Where the large vena umbilicalis sinistra enters the liver from the body-wall the ventral mesentery may be said to commence, and it is continued caudally from the posterior aspect of the vein as a thin membrane (fig. 17) connecting mesentery and body-wall for about twenty sections ( $10\mu$ ). Behind this it is produced as dorsal and ventral pillars on the mesenteric edge and ventral body-wall respectively as far back as the umbilical coelomic diverticulum.

Fig. 17 shows the incomplete foramen of Winslow, or hiatus communis recessuum, through which the lesser peritoneal cavity has a wide communication with the greater. The hiatus is bounded above by the point of separation of the caval mesentery from the dorsal surface of the liver, behind by the caval mesentery with the early inferior vena cava, in front by the posterior surface of the right lobe of the liver, and is widely open

to the right and below. From this opening the lesser peritoneal cavity extends orally and expands in three main directions: (*a*) ventrally between the stomach and right lobe of the liver, recessus hepato-entericus; (*b*) to the left over the dorsal aspect of the pylorus and distal part of fundus, r. mesenterico-entericus; and (*c*) orally, partially separating the lower end of the oesophagus and the stomach from the right lung anlage, r. pneumato-entericus (*cf.* figs. 13, 15, 16, and 17).

Caudal to the origin of the pancreas the dorsal mesentery follows the main intestinal torsion, and merits no special description (figs. 19 and 20).

My thanks are due to Geheimrat Professor Wiedersheim for permitting me to work in his laboratory over an extended period, and for placing the resources of the Institute at my disposal; to Professor Keibel for the loan of his embryo and continuous supervision and helpful criticism during the course of the work; and to Dr von Berenberg-Gossler for many valuable suggestions.

FREIBURG IN BREISGAU,  
*April* 1914.

# LIST OF PRINCIPAL ABBREVIATIONS.

A.br. = brachial artery.	p. = profunda.	s. = superficialis.	Ao. = aorta.	A. = aortic arch.	C. = caudal.	d. = dorsal.
A.c. arteria centralis (of spinal cord).			Ap. appendix.			
A.c.e. carotis externa.			At.c. atrial canal.			
A.c.i. carotis interna.			B.A. bulbus arteriosus.			
A. cœl. cœliac artery.			B.cap. Bowman's capsule.			
A.cl. cloacal branch of caudal aorta.			B.D. common bile duct.			
A.D.S. dorsal segmental artery.			B.E. eparterial bronchus bud.			
A.f.b. artery of fore-brain (a. cerebri ant. et med.).			B.L. lateral bronchus bud.			
A.m.s. arteria mesenterica superior.			B.S. bulbar swelling. A and B = proximal. 1 and 3 = distal.			
A.P. pulmonary artery. l. = left.			B.St. stem bronchus.			
		r. = right.	Cæc. cæcum.			
A.r.d. a. radicularis dorsalis.			C.D. cystic duct.			
A.r.v. a. radicularis ventralis.			Ch.d. chorda dorsalis.			
A.S. subclavian artery.			Cl. cloaca.			
A.Spl. splenic artery.			Co. colon.			
A.U. umbilical artery.			D. duodenum.			
A.V. vertebral artery.			D.A. ductus arteriosus.			
A.W. Wolffian artery.			D.br. ductus branchialis.			
Ad. adrenal cortex.			D.E. ductus endolymphaticus.			
Al. allantois.			Ep.B.III. epithelial body of third pharyngeal pouch.			

- F.B. = fore-brain.  
 G.B. gall-bladder.  
 G.F. Froriep ganglion.  
 Gl. Wolffian glomerulus.  
 G.S. spinal ganglion.  
 G.c. cervical ganglion. d. = dorsal.  
     l. = lumbar. V. = Trigem-  
     inal.  
 H.B.r. roof of hind-brain.  
 H.C.R. hiatus communis recessuum.  
 H.D. hepatic duct.  
 Hem. cerebral hemisphere.  
 Hy. hypophysis.  
 Il. ileum.  
 J. organ of Jacobson.  
 K. kidney.  
 L. liver.  
 La. larynx.  
 M.B. mid-brain.  
 M.p.p. pleuro-pericardial membrane.  
 M.p.pt. pleuro-peritoneal membrane.  
 Mx. maxilla.  
 My.O.3. third occipital myotome.  
 N.acc. accessory nerve.  
 N.B.P. brachial plexus.  
     N.c. cervical nerve.  
 N.Ch.T. chorda tympani.  
     N.d. dorsal nerve.  
     N.E. nervus epibranchialis.  
     N.La. laryngeal branch of N. X.  
 N.L.P. lumbar plexus.  
 N.Md. mandibular nerve.  
     Mx. maxillary n.  
     N.O. ophthalmic n.  
     N.ph. phrenic n.  
     N.ps. superficial petrosal n.  
 N.rad. radial n.  
     N.S. sacral n.  
     N.X. vagus n.  
 N.XII.d. descendens hypoglossi.  
 Neu. neuromere.  
 N.L. naso-lacrimal groove.  
     O. oesophagus.  
 OP. optic anlage.  
 OT. otic vesicle.  
 P. pericardium.  
 P.D. = dorsal pancreas.  
 Ph.p. pharyngeal pouch.  
 Pl. placode.  
 P.R. pulmonary ridge.  
 P.U. pillar of Uskow. d. = dorsal.  
     v. = ventral.  
 P.V. ventral pancreas.  
 Py. pylorus.  
 R. rectum.  
 R.C. ramus communicans.  
 R.H.E. recessus hepato-entericus.  
 R.M.E. „ mesenterico-entericus.  
 R.P.E. „ pneumato-entericus.  
     S. spleen.  
 S.A.P. septum aortico-pulmonale.  
 S.B.D. distal bulbar septum.  
 Sp.s.v. spatium septo-valvulare.  
     S.s. sinus sagittalis.  
     S.v. sinus venosus.  
 Sy. sympathetic cord and ventral  
     branches.  
 T. trachea.  
 T.A. truncus arteriosus.  
 Th. thyroid anlage.  
     t.s. secreting Wolffian tubule.  
 Ty. thymus anlage.  
 V.c. caudal vein.  
 V.Cu. Cuvierian vein.  
 V.C.I. vena cava inferior.  
 V.Hep. hepatic vein. c. = common.  
     l. = left. r. = right.  
     V.Is. ischiadic vein.  
     V.m.s. superior mesenteric vein.  
     V.om. omphalo-mesenteric v.  
     V.p. pulmonary v.  
     V.r.a. ramus arcuatus.  
 V.r.ang. ramus angularis.  
     V.S. subclavian vein.  
     V.sub. subcardinal v.  
 V.T.E. thoraco-epigastric v.  
     V.U. umbilical vein.  
     V.Ul. ulnar vein.  
     V.V. venous valve.  
 W.D. Wolffian duct.  
 W.R. Wolffian ridge.

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#### EXPLANATION OF PLATES I. AND II.

Fig. 1. Photograph of the Embryo.  $\times 4$  ca.

Fig. 2. Drawing of a portion of a section containing a "cellular ramus communicans." Ao., aorta; N.c.3, third cervical nerve.  $\times 1120$  ca.

Fig. 3. Drawing of a model of the right olfactory region, seen from below and somewhat from the right side. Mid.l., middle line; Mx., maxilla; N.L., nasolacrimal groove; OP., optic anlage.  $\times 40$  ca.

Fig. 4. Drawing of a portion of a section passing almost horizontally through the upper part of the third pharyngeal pouch. Ep.B.III., anterior wall or anlage of the epithelial body of the pouch; Ty., posterior wall or thymic anlage.  $\times 1120$  ca.

Fig. 5. Drawing of a model of the pancreatic outgrowths with the biliary ducts and a portion of the right lobe of the liver. D., duodenum; G.B., gall-bladder; H.D., hepatic duct; L., liver; P.D., dorsal pancreas; P.V., ventral pancreas; St., stomach; V.om., omphalo-mesenteric vein; V.v., vitelline vein; V.m.s., superior mesenteric vein.  $\times 75$ .

Fig. 6. Drawing of a model of a part of the intestinal loop, with a portion of the superior mesenteric artery. A.m.s., superior mesenteric artery; Ap., appendix; Co., colon; Il., ileum.  $\times 75$ .

Fig. 7. Drawing of some blood-cells from the spatium septo-valvulare of the heart. *a*, *b*, *c*, erythrocytes; *d*, leucocytes.  $\times 1500$  ca.

Fig. 8. Drawing of three "genital cells." *a*, cell lying in the mesentery, from the lower dorsal region; Cæ., cœlomic epithelium; *b*, cell from the mesoderm dorso-mesial to the cœlomic epithelium, with a neighbouring mesoderm cell; *c*, cell from the left genital region.  $\times 1120$  ca.



FIG. 1.—Human embryo of 8.5 mm.  $4\times ca.$

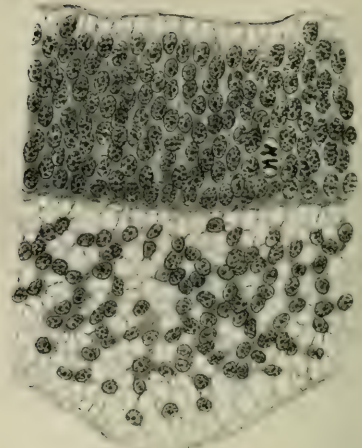


FIG. 4.  $\times 1120 ca.$

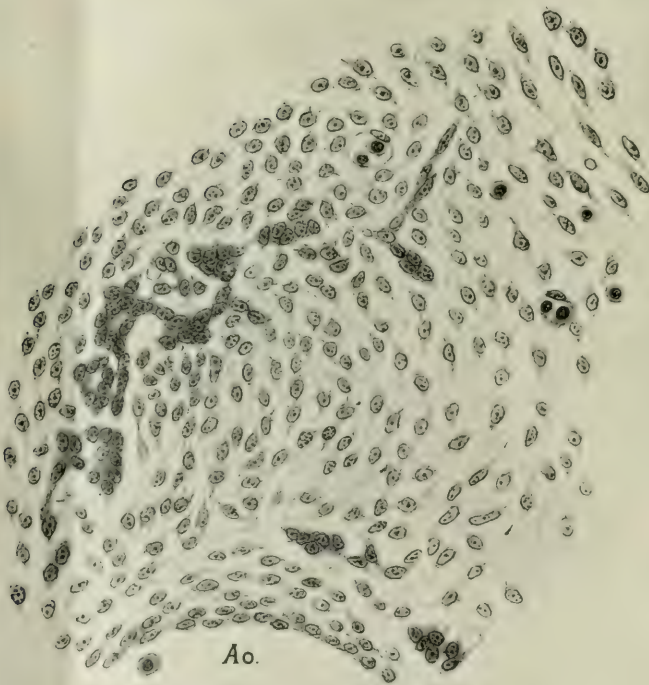


FIG. 2.  $\times 1120 ca.$

N.c.3.

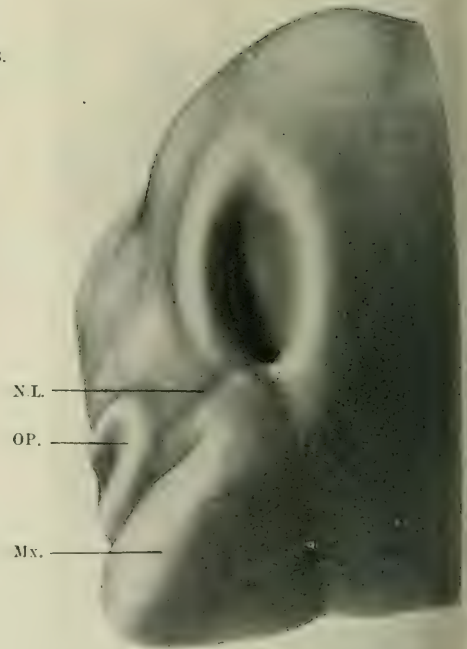


FIG. 3.  $\times 40 ca.$

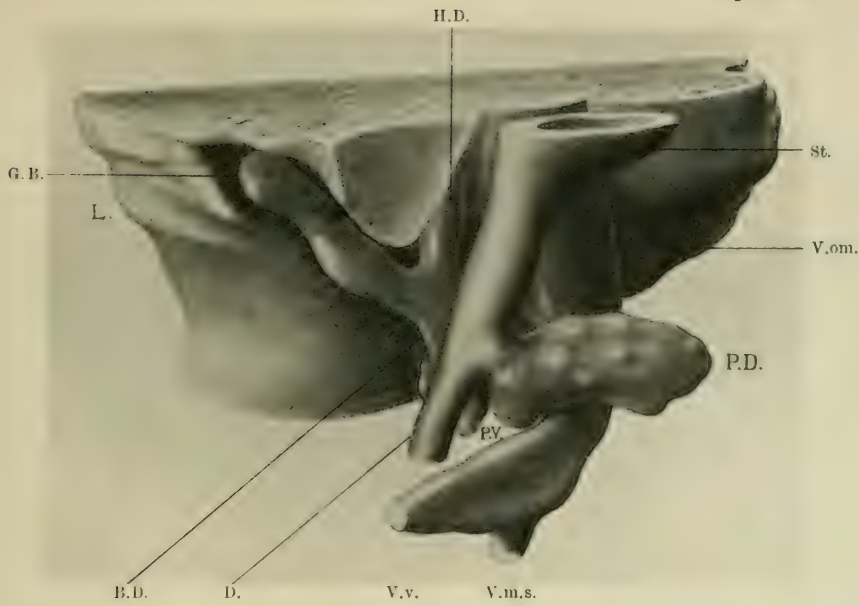


FIG. 5.  $\times 75$ .

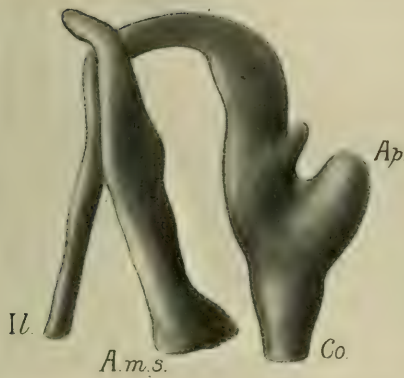


FIG. 6.  $\times 75$ .



FIG. 7.  $\times 1500$  ca.

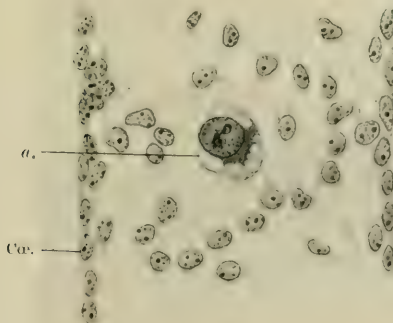


FIG. 8.  $\times 1120$  ca.



## DENTAL MUTILATIONS IN NEOLITHIC HUMAN REMAINS.

By J. WILFRID JACKSON, F.G.S., *Manchester Museum.*

THE object of this paper is to bring forward some cases of dental mutilations met with in prehistoric human remains found in a cave, known as Dog Holes, on Warton Crag, Lancashire.

Reference has already been made to two of the cases in a report to the Lancashire and Cheshire Antiquarian Society (see *Trans.*, vol. xxx., 1913, p. 108 *et seq.*); but, as it is possible that the *Transactions* of this Society do not reach the majority of students of anatomy and anthropology, it has been suggested that the subject would receive greater attention, and reach a wider circle of scientists, if brought forward in the *Journal of Anatomy and Physiology*.

So far as I can ascertain, the remarkable features exhibited by these specimens are quite unique, and have not hitherto been recorded in any other British specimens.

It is hoped, therefore, that this notice will lead to further investigations being made among the numerous human remains hitherto found in Britain and elsewhere, and result in other discoveries of dental mutilations.

The only evidence of missing teeth in British fossil human remains appears to be that of the famous and much disputed Galley Hill skeleton described by Mr E. T. Newton in 1895.<sup>1</sup> In his description of the lower jaw the author remarks: "On each side of the symphysis the alveolar border is broken; but while portions of the alveoli for the two outer incisors are preserved, there are no traces of the alveoli for the two median incisors, which must have been either very short or else lost during life, and the alveoli filled up by bone."

The history of the Warton finds is as follows:—In 1909, whilst excavating in the Dog Holes cave, I discovered a number of human remains, amongst them being a lower jaw which was remarkable for the absence of the second premolar teeth on either side, and with all traces of the alveoli obliterated. I also met with an upper jaw from which the two median incisors had been extracted some time before death.

In 1912, whilst conducting further excavations at the same cave, I had the good fortune to discover another human lower jaw exhibiting

<sup>1</sup> *Quart. Journ. Geol. Soc.*, vol. li. (1895), p. 508.

exactly the same remarkable dental mutilations as in that found in 1909. This was also associated with numerous other human remains, including the skeleton of a dwarf, all coming from a somewhat lower horizon than those of the previous excavation. The jaws of all these, so far as could be ascertained from their fragmentary condition, were quite normal.

Associated with the human remains in this cave were various other objects, such as flint-flakes, rude hand-made pottery (one fragment), animal bones, etc., all of which pointed to the cave having been used as a place of sepulchre, as was the case in the Neolithic caves at Perthi Chwareu, Denbighshire, North Wales.<sup>1</sup>

The close parallelism in the physique of the human remains from the North Wales and Warton caves is noteworthy, and the circumstantial evidence points strongly to the Dog Holes remains being of the same age as those of Perthi Chwareu, *i.e.* Neolithic.

The following is a full description of the mutilated jaws:—

*Lower jaw, 1909.*—This jaw is very massive in build, and undoubtedly male. Teeth present, first and third molars on right side: first premolar, first and second molars on left. With the exception of both second premolars, the remaining teeth are represented by their sockets. The crowns of the teeth show a fair amount of grinding down, especially the first molars; the third right molar has evidently just come into use, as the flattening has only just commenced. Compared with the 1912 jaw, and considering the age of the individual to which the jaw belonged, the wearing down is not advanced. The depth of the jaw at the symphysis is 36.5 mm.; behind the second molar, 29.2 mm. The width of the bite is 64 mm.; the length, 44 mm.<sup>2</sup> The lengths of the individual teeth are:—

First right and left molars . . . . .	11.5 mm.
Second left molar . . . . .	10.5 "
Third right molar . . . . .	9.75 "
First left premolar . . . . .	7.5 "

Unfortunately the condyles and the coronoid processes of both sides of the jaw are broken, so that the dimensions of these parts cannot be ascertained.

*Lower jaw, 1912.*—This jaw is of much weaker construction than the one described above, and in all probability is to be referred to the female sex. The teeth present are the first and second molars of each side and the first premolar of the right. The canines and incisors are represented by their sockets. The third molars have not yet appeared, so

<sup>1</sup> See *Journ. Ethnol. Soc. London*, vol. ii., 1871, p. 440, and Dawkins' *Cave Hunting*, 1874, p. 149.

<sup>2</sup> Measured by Dr Keith's method, *Ancient Types of Man*, 1911, p. 41.

that the individual was probably not more than sixteen years of age, unless we assume a retardation in their eruption. The first right premolar is strongly inclined backwards in the direction of the first molar, and this inclination has resulted in the crowns of the two upper opposing premolars



being almost equally worn.<sup>1</sup> It is very probable that the tooth was disturbed in extracting the adjoining premolar.

The grinding down of the teeth has been much greater than in the 1909 jaw, and the nature of the wearing, especially of the first molars, suggests movement in a backward and forward direction, and not lateral motion.

The difference in wear is the more remarkable when one considers that this jaw belongs to a younger person compared with the 1909 jaw.

<sup>1</sup> A fragmentary upper maxillary containing several teeth was found alongside this jaw.

The depth of the jaw at the symphysis is 30 mm.; behind the second molar, 25 mm. The width of the bite (between exteriors of  $M_2$ ) is 61 mm.; the length (mid-point of line behind second molars), 35 mm.

The lengths of the teeth are:—

First right and left molars <sup>1</sup> . . . . .	8.5 mm.
Second right and left molars . . . . .	10.0 "
First right premolar . . . . .	7.0 "

The ascending ramus is somewhat broad for the size of the jaw, and possesses only a medium sigmoid notch.

In close proximity to the above mutilated jaw and upper maxillary was the greater part of a human cranium of dolichocephalic type, giving a cephalic index of .741. (Length, 182 mm.; breadth, 135 mm.) This skull also presents female characters.

*Upper jaw, 1909.*—This consists of two very weathered portions which fit together fairly accurately along the middle line of the palate. The teeth present are: right side,  $M_{2,1}$ ,  $PM_{2,1}$ ,  $C$ ,  $I_2$ ; left side,  $M_1$ ,  $PM_{2,1}$ ,  $C$ ,  $I_2$ . The socket is present for the left second molar, and portions of the sockets for both third molars. Both the two median incisors have been extracted some time previous to death, and both alveoli show signs of closing up, but are not altogether obliterated.

The teeth are remarkable for the amount and nature of their wear, large areas of dentine being exposed, surrounded by thick walls of enamel.

The wearing down of the teeth is quite unlike that presented by the two lower jaws just described, as well as that of other associated examples, where the crowns have been worn down to a uniform level. In the upper jaw the grinding, especially of the premolars, canines, and incisors, has taken place on the inner or lingual faces of the teeth, with the result that this face of each tooth is worn down almost to the alveolus. From this it is quite evident that the teeth of the lower jaw passed up behind those of the upper, when the jaws were closed.

Unfortunately, owing to the imperfect state of this specimen, the length of the palate cannot be accurately ascertained, but it cannot have been much more than 50 mm.: the width between the outer borders of the second molars is approximately 66 mm.

To the above records of missing teeth in British prehistoric human remains can also be added that of another hitherto unnoticed instance. In searching through the large number of human remains from the Perth Chwareu caves (now in the Manchester Museum), I discovered another

<sup>1</sup> These teeth are crowded against  $M_2$ .



example of an upper jaw where the two median incisors have been removed, but in this case both alveoli are completely grown up with bone. The specimen is very imperfect, and only four teeth are preserved, these being the canine, second premolar, first and second molars of the right side, all of which are well worn. The first premolar and second incisor of this side, as well as the second incisor of the left, are represented by their sockets. The remainder of the left side is broken away. The width across the palate, which is rather flat, is 34 mm. from the outer border of the second molar to the middle line, = 68 mm. for the total width. The length is approximately 53 mm., but the absence of the last molar renders this uncertain.

The dental mutilations in the remains just described open up a wide field for speculation in view of the widespread occurrence of similar practices among certain African tribes at the present day. Dr W. L. H. Duckworth has recently described in the pages of this Journal<sup>1</sup> an Ashanti skull from which the four upper incisors had been removed, evidently in early childhood. He further states that Dr Sergi met with the occurrence of the complete removal of all of the upper incisor teeth in seven out of a collection of twenty-nine crania from rock-hewn tombs in Abyssinia. The tombs are referred to the fifth century A.D., and the crania are said to represent a Hamitic, *i.e.* non-negroid stock. As shown by Sergi and others, the practice of removing incisor teeth is characteristically East African.

The Ashanti skull is still more remarkable from the fact that the first molar tooth of the upper set has also been lost on each side, the small amount of wear on the corresponding lower teeth ( $M_1$ ), the crowns of which are elevated above those of the adjacent molars, showing that the upper first molars were lost at an early date.

A further instance of dental mutilations on the West Coast of Africa is given by Mr Charles Partridge in his work on the *Cross River Natives* (1905). On p. 216 the author states that the natives have one of the incisor teeth removed at initiatory ceremonies.

Sir Harry Johnston,<sup>2</sup> in speaking of the Masai people, states that "almost all the men and most of the women knock out the two lower incisor teeth, a very ancient custom inherited from the Nilotic stock, which was their origin, for amongst these people the removal of the lower incisor teeth is a very common practice." The same writer also states that the Bantu Kavirondo and the Ja-luo usually pull out the two middle incisor teeth of the lower jaw (*op. cit.*, p. 728), and it may also occur amongst the latter people, as amongst the Lango tribes to the north, that

<sup>1</sup> Vol. xlv., April 1912, p. 215.

<sup>2</sup> *The Uganda Protectorate*, vol. ii. p. 863.

not only the four incisors, but even the canines, are taken out, at any rate from the mouths of boys (*op. cit.*, p. 783). The custom of extracting the four lower incisors is also prevalent amongst the Banyoro, a mixture of Hamitic and Nilotic elements, the practice, no doubt, having been learnt from the neighbouring Nilotic tribes (*op. cit.*, p. 581).

Quite recently the Rev. C. Lea-Wilson, in the course of his missionary work in the neighbourhood of the Bahr-el-Ghazal, Sudan, met with a race of people known as "Jieng," amongst whom, for some reason, apparently unknown to themselves, the adults have six of their lower teeth removed.

In 1910 Dr Elliot Smith<sup>1</sup> recorded the discovery, among Ptolemaic-Roman burials in Nubia, of a skull of a negress with all the lower incisors removed, and remarks that the practice of removing these teeth appears to be generally derived from the Dinka and allied Nilotic populations. He informs me that he has seen many examples of such dental mutilations in negroes buried in Nubia at various periods going back as far as the time of the Egyptian Middle Kingdom (*circa* 2000 B.C.): and further that Dr Derry recently showed him a case, obtained by Professor Flinders Petrie from a grave in Lower Egypt, said to be Late Predynastic, in which the median incisors had been removed.

A further remarkable case of dental mutilations is referred to by Dr John Cameron in his report on the anatomy of two Egyptian mummies of the XIIth Dynasty, now preserved in the Manchester Museum.<sup>2</sup> An examination of the skull revealed the startling fact that the right lateral incisor of the upper jaw had been removed in some way during life. Curiously enough, the removal of an upper incisor tooth completes the operation of sub-incision among the aboriginal Australians.

Many of the Australian tribes are in the habit of knocking out both upper incisors; others vary the custom by the removal of the right incisor only, and sometimes the left, and in most cases this custom is closely associated with the ceremonial of initiation. No definite explanation as to the significance of the custom can be elicited from the natives; it appears to have been handed down from time immemorial by their forefathers. As stated by Dr Cameron (*op. cit.*), the explanation which naturally suggests itself is that the absence of the tooth would indicate to strangers that the individual had gone through the ceremonial.

In some instances, as for example among the Arunta and Kaitish tribes, the original connexion with the rites of initiation appears to have been lost, and the operation has become, to a large extent, quite optional. It is

<sup>1</sup> *Arch. Surv. Nubia*, Bull. No. 5, 1910, p. 23, etc.

<sup>2</sup> See *The Tomb of Two Brothers*, by Miss Margaret Alice Murray, 1910 (Manch. Mus. Handbook).

performed usually early in life and before marriage, but this is not always the case, as fully grown men are operated upon in many cases.

The perpetuation of the custom among these tribes is largely influenced by the fear of ridicule if the operation is not performed.

Further information regarding this and other customs is to be found in the works of Professors Baldwin Spencer and F. J. Gillen, Dr A. W. Howitt, and others.<sup>1</sup>

Mr W. H. Bird, in *Anthropos* (vol. vi., 1911, p. 174), also remarks on the initiation ceremonies of the Buccaneer Islanders, North-Western Australia, part of which consists of the knocking out of the two front teeth of the upper jaw of boys when they attain the age of twelve years. He also speaks of the occurrence of the same mutilation having been noticed in the case of one or two girls among these islanders.

At this point it may not be out of place to call attention to what might be considered another form of dental mutilation in Neolithic remains, *i.e.* the practice of filing the teeth. Dr Edward T. Wilson, in his recent presidential address to the Cheltenham Natural Science Society, mentions an interesting case among some human remains from a long barrow at Belas Knapp, near Charlton-Abbots, Gloucestershire, in which the upper incisors had been filed down.

This custom of filing certain of the teeth, often in quite a grotesque way, is common among several low races in various parts of the world; for instance, it is prevalent among the pagan tribes of the Malay Peninsula,<sup>2</sup> also among the Maya, Modoc, and Zapotec tribes of the Pacific States of America,<sup>3</sup> the latter filing the teeth down to the gum, or even below it.<sup>4</sup>

Dr A. Hrdlicka informs me that the only dental mutilation of which he has a direct and positive knowledge is the filing of the front teeth among the prehistoric Tarasco, and some other tribes in Central and Southern Mexico. He states further that he has often seen in prehistoric skulls from Mexico and other localities a complete loss of the median upper incisors, and it is quite possible that in some of these cases at least the teeth were removed ceremonially; but he has no absolute proof of such a practice, and has never met with it among the living Indians. Personally, he is inclined to believe that the practice has existed in some parts of America.

<sup>1</sup> An older and fuller account of the initiation ceremony among the Australians is given in Governor Collin's *Account of New South Wales*, 1804, under the name Yoo-long-erah-bah-diang. In this there are illustrations of the method whereby the tooth was knocked out. Such initiation ceremonies were limited to males. See p. 374 and the plates following.—(A. M.)

<sup>2</sup> See Skeat and Blagden's *Pagan Races of the Malay Peninsula*, London, 2 vols., 1906.

<sup>3</sup> See Bancroft's *Native Races of the Pacific States*, London, 5 vols., 1875.

<sup>4</sup> See W. Turner, Notice of Cranium of a Manganya Negro in *Proc. Roy. Phys. Soc.*, Edinburgh, 25th January 1865; figure showing filing of the upper incisors.



In connexion with the custom of filing the teeth, Dr Elliot Smith has suggested that if the operation was carried too far, so as to expose the pulp cavity, it might result in the ultimate decay and loss of the particular teeth; but evidence on this point is lacking.

The discovery of dental mutilations in British prehistoric remains appears to me to be of considerable interest and importance, and naturally raises the question as to how these early people acquired such a practice: also whether any significance can be attached to its occurrence.

There can be no doubt that this practice among the British Neolithic people is genetically related to similar practices elsewhere, especially those in the neighbourhood of Eastern Africa; and it is of no little importance to note its occurrence among the primitive Egyptians, some 3400 years B.C., a date which is probably only slightly earlier than that of the Neolithic age in Britain.

It seems evident, therefore, that these early Neolithic people had retained some remnant of a rite or custom, formerly in use amongst themselves, or adopted from neighbouring tribes during their migration from their original home in the East.

We might even assume, from the presence of mutilations in so few of the jaws of what might be looked upon as one clan or family-group, that, as in the case of some of the Australian aborigines, the significance of the operation might likewise have been lost, and the practice so degenerated into a merely optional custom, through the isolation of the tribes in their northward migration, or through some advance in civilisation.

The questions raised by this inquiry are decidedly interesting ones for future investigation, and I feel confident that, now attention has been called to this curious practice of dental mutilations in Neolithic remains, other hitherto unnoticed occurrences will be forthcoming, and result in establishing a cultural chain linking the British Neolithic tribes with the Pre-Dynastic Egyptians, by way of the Iberian Peninsula and Northern Africa.



THE SUPRACONDYLOID TUBERCLES OF THE FEMUR AND  
THE ATTACHMENT OF THE GASTROCNEMIUS MUSCLE  
TO THE FEMORAL DIAPHYSIS. By J. S. B. STOPFORD, M.B.,  
Ch.B. (Manch.), *Senior Demonstrator of Anatomy, University of  
Manchester.*

SOME considerable time ago Mr E. E. Hughes, F.R.C.S., late Lecturer in Clinical Anatomy at this University, directed my attention to a tubercle on the popliteal surface of the femur immediately proximal to the medial condyle.

From that time I noticed it so frequently that some months ago I decided to examine a number of femora to ascertain its constancy and make some dissections to attempt to determine its significance. I examined in all 286 adult femora, 112 from our anatomical collection and 174 from the Nubian collection which is at present stored in the medical museum of this school. For the latter privilege I should like to take this opportunity of thanking Professor Elliot Smith, who is preparing a full anthropological report on these remains.

Out of this series the tubercle was only absent in one case (35 per cent.), so that its presence may be regarded as constant—in fact, more constant than many of the other prominences which are universally taught to students and described in all the standard text-books.

The position of the tubercle is also constant, being situated on the popliteal surface, almost immediately proximal to the medial condyle, and just lateral to the medial epicondylar line. From its position it is obviously diaphysal in origin.

Although its occurrence and position appear constant, its size and shape are extremely variable. In all the 285 specimens it was sufficiently pronounced to make it possible to distinguish the medial aspect of the lower extremity of the bone solely from its presence.

In the majority (80 per cent.) it appeared as a well-developed nodular elevation, which was better marked distally where it terminated abruptly than proximally where it gradually merged into the shaft. It invariably had a broad base and a rough irregular surface which indicated the attachment of some strong muscular or ligamentous structure. In these cases it was considerably larger and more extensive than the adductor tubercle.

In 32 specimens (11·2 per cent.) it was only slightly developed and comparable in size and appearance to the tubercle for the quadratus.

In about 8 per cent. it was extraordinarily well developed, forming a large projection which in several cases extended for a distance of about one inch up the diaphysis. In this series the tubercle had a sloping superior surface which gradually merged into the shaft and which was



FIG. 1.—Photograph showing both medial and lateral supracondyloid tubercles.

fasciculated longitudinally, indicating that the force exerted by the structure attached to it was probably in a downward direction; the inferior surface ended abruptly and was rough and quite irregular, usually terminating rather less than a centimetre above the articular surface of the medial condyle.

The tubercle was invariably larger and better marked, as is to be expected in cases exhibiting osteo-arthritic changes. I failed to find it on the diaphysis of very young femora, and from the bones examined before the occurrence of complete fusion of the epiphyses I am inclined to conclude

that it makes its appearance about the fourteenth to the eighteenth year. I hope to refer to this point again in a future communication on the histological union between bone and muscle or tendon.

In the course of this examination I was somewhat surprised to find in 25 specimens (8·7 per cent.) a smaller and less defined tubercle situated



FIG. 2 —Photograph of lower end of femur from Nubian collection, showing mummified remains of the medial head of gastrocnemius muscle arising from the medial supracondyloid tubercle.

medial to the lateral epicondylar line, but rather nearer the epiphysis than the one just described on the medial aspect.

On making a dissection of the popliteal region to determine the significance of the medial supracondyloid tubercle, I found a strong fibromuscular fasciculus extending up to it, which at first sight appeared to be an upward prolongation of the ligamentum posticum, but on turning the medial head of gastrocnemius inwards it was seen to consist of deep fibres of origin of this muscle. Since this time I have made a number of special dissections of this region and have examined the origin of the

gastrocnemius muscle in over forty cases, and am now convinced that the origin of this part of the muscle is more extensive than usually described, and is very largely from the diaphysis. The most medial fibres which are tendinous appear to be the fibres most usually described, and arise from that part of the bone lying posterior to the adductor tubercle; but the

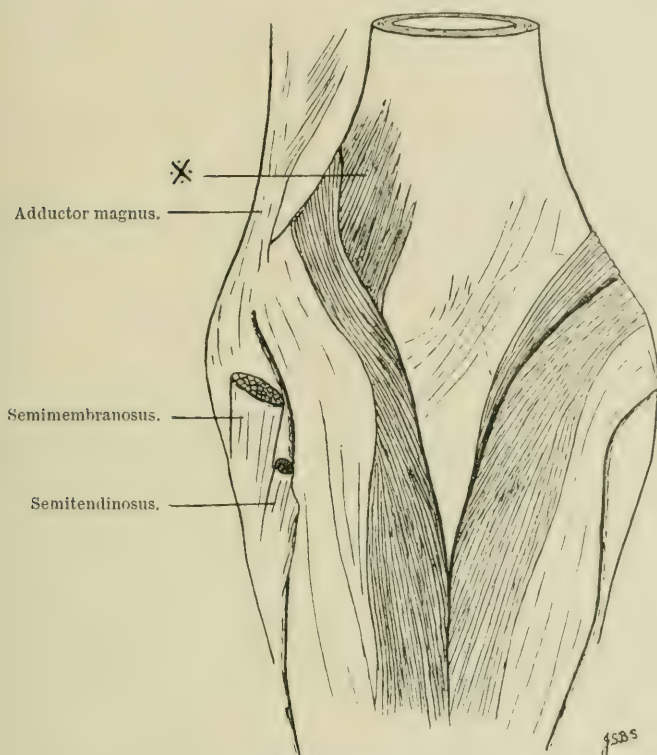


FIG. 3.—Drawing (from a dissection) of the origin of the gastrocnemius muscle.

\* marks the fibres attached to the medial supracondyloid tubercle.

more lateral and deeper fibres, which are practically always to some extent muscular, arise from the superior sloping surface of the medial supracondyloid tubercle. Consequently a large proportion of the fibres of origin of this head arise from the diaphysis and frequently extend for a distance of one inch or even more proximally along the shaft. Some of the deeper fibres, as usually stated, arise from that part of the capsule covering the medial condyle. On removing this head close to the bone it is seen that the origin is roughly triangular in shape (fig. 4), with the



apex directed proximally and the medial side of the triangle prolonged distally on to the epiphysis immediately behind the adductor tubercle.

In no case did I find the lateral head of the gastrocnemius arising from the lateral supracondyloid tubercle, but in the few cases in which this prominence occurred it was the deeper and more medial fibres of the plantaris muscle which gained origin from it.

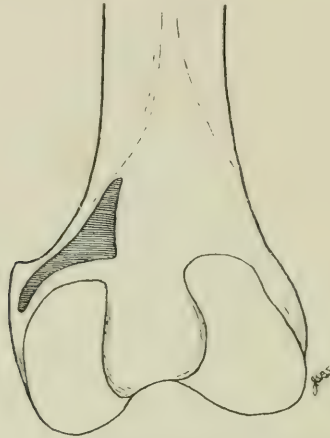


FIG. 4.—Diagram to show origin of medial head of gastrocnemius muscle from the femur.

The supracondyloid tubercles are briefly referred to by Poirier (1), and the medial one has been noticed more recently by Professor Parsons (2) in his examination of a large number of English femora; but this note seems worth recording if only to illustrate the constancy of the medial tubercle and to emphasise the diaphysial origin of such a large proportion of the gastrocnemius muscle.

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NOTE ON A CASE OF BIFID PENIS, WITH PENIAL HYPO-  
SPADIA. By J. A. PIRES DE LIMA, *Professor of Topographical  
Anatomy in the Faculty of Medicine of Oporto, Portugal.*

ON the 23rd April 1914 there entered into the Santo António Hospital at Oporto a man from the town of Valença, A. J. V., fifty-eight years of age, married, and employed as a farm labourer. Three days previous to his entry a bullock-cart laden with gorse ran over the external side of his thigh and gluteal region, producing serious internal injuries, which caused retention of urine and fæces.

On the introduction of a catheter, it was noticed that there existed curious anomalies in the genital organs, which I had the opportunity of studying, and which I am going to describe.

On the mere inspection of the penis, this organ is found to be short and widening considerably from behind forwards, ending in a double well-developed and imperforate glans. On examining the ventral surface, it is seen that the copulating organ lacks urethra in its greater extent: this canal finishes in a larger and rounded meatus immediately in front of the scrotum, and on the anterior part of the body of the penis the urethra is represented by a large groove turned downwards.

By palpation I verified that the corpora cavernosa, joined behind, diverge in front, forming an acute angle, and separating from one another at the distal extremity of the body of the penis, which, owing to this, is wide and flattened in front.

The body of the penis measures 10 centimetres in circumference, not only close to the pubis, where it is cylindrical, but also close to the glans: but here it is flattened, as I said, measuring in width, on the dorsal surface, 5 centimetres. The total length of the flaccid penis taken on that surface is 8.5 centimetres, of which 2.5 centimetres belong to the balanic part: on the ventral surface it measures only 6 centimetres in length, from the scrotum to the extremity of the glans.

The prepuce is double and very short, so that it cannot pass farther than the corona glandis, which is also double, with the consequent result that the double glans is totally uncovered.

On the median line of the dorsal surface, starting from the interstice between the two prepuces, there is a congenital scar, in the form of a raphe.

2 centimetres long. On either side of the median line, as can be seen in fig. 1, there is a series of radiated folds.

In front of the sulci retroglandularis there is a double glans, each distinctly divided by a deep intermedian groove. Each half appears as if it were a complete glans: they touch one another, and are both equal and symmetrical, so that it is sufficient to describe one of them only. Each one has the form of a triangular pyramid with its base turned towards



FIG. 1.—Dorsal surface.

the corresponding corpus cavernosum and a distal vertex. The internal surface is flat, and measures 2.5 centimetres from the extremity to the sulcus retroglandularis. The inferior surface is also flat and much smaller than the others, as the prepuce is more extensive on the ventral surface. The supero-external surface, regularly convex, presents wrinkles in some places. Both the corona and the sulcus retroglandularis have a normal appearance. As is natural, there is no sign of a frenum nor of Guérin's valve.

The urinary meatus, which is wide and round, infundibuliform, is situated 2 centimetres away from the scrotum, and 4 centimetres from the distal end of the penis.

In front of the meatus, as can be seen in fig. 2, the urethral canal is

represented by a deep groove, with its concavity turned downwards, and there can be seen some longitudinal folds.

The scrotum, as well as the testicles, seems normal, and the patient has no other apparent anomaly, except convergent strabismus of the left eye.

This genital malformation, according to the patient, did not affect his sexual functions. He has two daughters and three sons, two of whom are already married and have children. None of his descendants possess



FIG. 2.—Ventral surface.

any anomaly that resembles his. He does not think that any of his ancestors or relations have had any such malformations. As far as he knows, his parents were neither alcoholic nor syphilitic. His father was much older than his mother, and he must have been fairly aged when A. J. V. was born, he being the youngest of four brothers.

Evidently this is a case of hypospadias with penischisis. If the first of the malformations is common, the same is not the case concerning the bifidness of the copulating organ, which is very rare in man. Both have an embryological interpretation, as we will see, following closely the works of Tourneux (1) and Retterer (2, 3).



During the third month of gestation, on the ventral surface of the genital tubercle there are two genital folds, disposed in the antero-posterior sense, which limit the genital sulcus. The genital folds are joined together by their inferior free borders: the joining together begins to take place at the root of the penis, and then stretches progressively forwards to the vertex of the copulating organ. Thus originates the *pars cavernosa* of the urethra.

If there is a break in this process of adherence, instead of the normal urethral canal being formed a hypospadias takes place, and, according to the spot where the urethral evolution stopped, that hypospadias may be scrotal, penile (as in the present case), or merely balanic.

On the body of the penis, the superior angle of the genital sulcus disappears, owing to the junction of its lateral walls. On the glans, the lateral walls of the genital sulcus do not join completely on its dorsal surface, as is the case on the body of the penis; generally they adhere more especially on the posterior part of the glans, forming a mesodermic bridge (Guérin's valve), which limits inferiorly Guérin's sinus.

The anterior portion of the urethra has, consequently, the form of a vertical fissure on its dorsal surface, and it is wide on its ventral surface (*fossa navicularis*).

If the partial adherence of the lateral walls of the dorsal part of the balanic urethra continued as far as the extremity of the glans, a para-urethral fistula would be formed, which anomaly I have already had occasion to study in three individuals (4).

Retterer (2) considers the genital tubercle a dual organ, as being the result of the fusion of two even and symmetrical halves. The penis has, according to such views, the value of two formations which, developing one by the side of the other, joined together so as to form one single organ.

The junction of the two primitive halves of the penis did not take place completely in the present case. The two corpora cavernosa, joined at the pubic angle, separated afterwards, ending each in an independent glans.

This disposition is to be found generally in the Monotremata and Marsupialia, as can be seen in the zoological treatise of Sedgwick (5); and some authors, like Albrecht, mentioned by Guinard (6), and Morselli (7), consider the bifidness of the penis, or penischisis, in man, where it is so rare, as a regressive anomaly.

According to the investigations of Retterer (3) and other embryologists, the glans is not a mere expansion of the corpus spongiosum as was believed; the terminal and free end of the penis is rather constituted by the various elements which are to be found in the whole organ—that is, by the skin, by the corpora cavernosa, and by the corpus spongiosum.

The cases of hypospadias, and especially the specimen which I have described, support the opinion of Retterer. It is true that, in my observation, the two parts of the double glans, on the whole well developed, are nevertheless flattened and, so to speak, atrophied on their ventral surface, which seems to show that the corpus spongiosum did not contribute normally as an element of formation.

Some recent works of anatomy still say that the glans is merely an expansion of the corpus spongiosum, superposed by its base on the anterior termination of the corpora cavernosa. However, I think Retterer's views concerning the structure of the free extremity of the penis plainly demonstrated.

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A HUMAN EMBRYO OF TWENTY-SEVEN PAIRS OF SOMITES,  
EMBEDDED IN DECIDUA. By DAVID WATERSTON, M.D.,  
*King's College, London.*

HISTORY.

IN the *Journal of Obstetrics and Gynecology of the British Empire* of February 1910, a communication was published from Dr (now Professor) Watson, of Toronto University, and Mr Henry Wade, on "The Histological Changes associated with an Early Abortion, with special reference to the Vessels of the Decidua."

That communication contained an account of a decidual cast of the uterus which the authors had examined, and which was found to contain, embedded in its wall, a young human embryo.

The observations of these authors were restricted to an examination of the decidua, and chiefly to the pathological changes which it showed. After completing their examination, they were so kind as to hand to me the sections which they had prepared, in order that the structure of the embryo and its annexa might be worked out. I wish to express to these two gentlemen my most cordial thanks for this opportunity of examining a most important and valuable specimen.

The full history of the specimen is given in the publication mentioned above, and it is necessary to repeat here only those facts which relate to the age and condition of the embryo. They are as follows:—

"In December 1907 the patient had gone beyond her usual menstrual period by ten days, and then began to bleed slightly. On the supposition that she was pregnant, she was instructed to keep carefully anything that came away, and next day she brought to us a piece of tissue, a complete decidual cast of the uterus, on one wall of which was visible, as a small pea-like elevation, the ovum.

"The uterine decidual cast is a piece of membrane triangular in shape, measuring 3·9 cms. along the base, and 4·5 cms. along each wall. The external surface is shaggy in appearance, while on opening the sac the internal surface presents a more or less smooth surface, slightly pitted, and thrown into smooth elevations. Towards the apex of the cast, corresponding to the position of the os internum, is a small pea-like elevation, smooth on the surface and surrounded by a ridge of the mucous membrane rather

bigger than the other ridges present. This pea-like elevation represents the ovum covered with decidua, and measures 8 mm. in diameter. The specimen was hardened in formalin and embedded in paraffin, and a series of 1800 serial sections were made through the ovum and adjacent parts of the decidua.

"In the sectioning, we were fortunate in cutting the embryo almost transversely, and the result has been that the sections show the relations of the different parts of the embryo and its membranes with almost diagrammatic clearness."

Examination of the sections showed that a well-preserved human embryo had been obtained at an early stage of development. The interest and value of the specimen were enhanced by the fact that the whole chorionic vesicle was intact within a complete decidual capsule, and it therefore seemed probable that an examination would prove of value not only as regards the embryo itself, but also in throwing light upon an early stage of embryonic implantation and placental formation.

In the present paper I propose to give for the most part a descriptive account of the embryo and its organs and membranes, indicating briefly the bearing of some of the facts elicited upon the present state of our knowledge.

#### METHODS.

The sections had been stained some with hæmatoxylin and eosin, some by iron alum hæmatoxylin, and some with alcoholic eosin and methyl blue. The histology of the embryo and its membranes was, on the whole, good. Mitotic figures were visible in many of the embryonic tissues. Portions of the neural tube showed some shrinkage, but the other tissues, including the heart, blood, and gastro-pulmonary tissues, were in good preservation.

The deciduæ showed pathological changes involving mainly the vessels, but the embryo itself appeared to be quite unaffected by organic pathological changes.

In order to work out the external form of the embryo and the general relation of the various parts a wax-plate reconstruction was made, at a magnification of 50 diameters, of the embryo with its yolk-sac, the amnion, and the adjacent zone of the chorion and decidua.

This degree of enlargement did not bring out all the details of the internal structure of the embryo, and subsequent reconstructions were made at a magnification of 200 diameters, both plastic and graphic, from which details of structure were worked out. The sections had not been cut with "ritz" lines for reconstruction, and it was necessary to use the decidua as a guiding structure, together with the photographs and



measurements which had been taken of the nodule before it was sectioned.

Comparison of the model with the photographs and the measurements showed that an accurate reconstruction had been obtained.

Thus the measurement—taken directly from the specimen before it was sectioned—of the transverse diameter of the nodule which projected into the uterine cavity was 8 mm. In the reconstruction at 50 diameters the corresponding measurement in the model was almost precisely 40 cms., and the degree of correspondence reached in this dimension leads one to believe that the measurements of the embryo, etc., may be relied upon as being exact.

#### GENERAL ARRANGEMENT OF PARTS.

The arrangement and something of the structure of the parts of the specimen are seen in fig. 1, which is taken from a section which cuts across the embryo, yolk-sac, body stalk, as well as the chorionic wall and decidua, and in fig. 2, which is taken from a wax-plate reconstruction.

The chorionic vesicle is seen lying in the implantation cavity in the decidua. The cavity of the vesicle contains an irregular reticulum, the "magma réticulée" of Eternod,<sup>1</sup> and towards one end lies the embryo, the amnion, yolk-sac, and the body stalk.

The thin layer of decidua which separates the implantation cavity from the cavity of the uterus is the decidua capsularis; the layer on the opposite side which has separated from the uterine wall is the decidua basalis; while around the equator of the implantation cavity, at the meeting of these two portions, is the decidua marginalis.

The decidua forms a complete capsule for the chorionic vesicle, and it did not show anywhere any signs of the perforation aperture.

The decidua capsularis is thin, measuring only .2 mm. in its transverse diameter, while the decidua basalis is much thicker, measuring about 1 mm. in average thickness. The free surface of the former, directed towards the cavity of the uterus, is quite smooth, while the surface of the decidua basalis, where it had separated from the uterine wall, is rough and shaggy.

The decidua showed the histological features characteristic of decidual tissue, which do not need to be described at length.

The layer next to the implantation cavity showed a finely reticulated or laminated appearance, and stained deeply with eosin. It consisted of a fine network of fibres resembling fibrin, lying parallel to the free surface, and in the meshes of the network there were large numbers of red blood cells.

<sup>1</sup> Eternod, *Des premiers stades de l'œuf humaine, etc.*, Nancy, 1905.

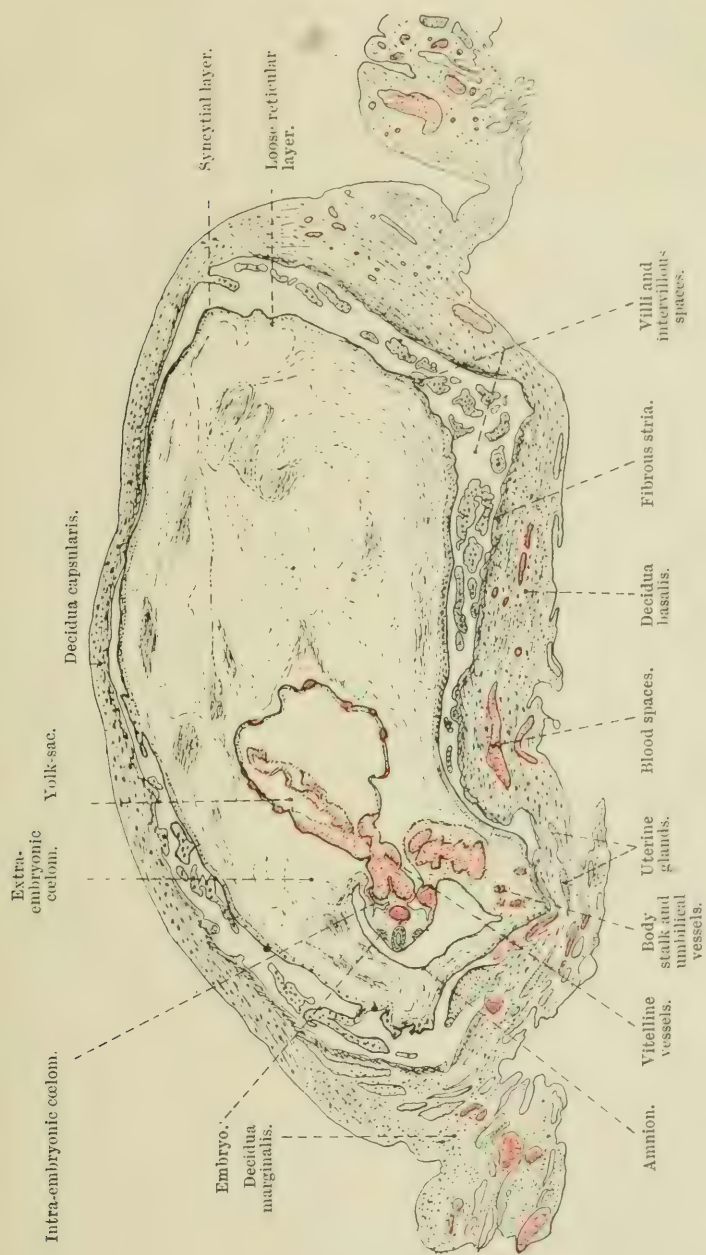


FIG. 1.—Section of embryo, yolk-sac, body stalk, chorion, and decidua.

To this surface the ends of some of the villi adhered, though for the greater part the villi terminated freely, and they did not anywhere perforate this laminated layer of fibrin. The fibrin stria was most distinct and thickest in the regions where the villi were most numerous, and the appearances certainly corroborate the view that the "fibrin zone" is produced by the necrotic action of the syncytial layer of the chorionic wall upon the adjacent uterine tissue<sup>1</sup> rather than as a result of syncytial degeneration. The intervillous spaces contained red blood cells, in some places in large numbers.

In the decidua basalis were many enlarged uterine glands, which, in some cases, opened into the intervillous space. There were also numerous dilated spaces containing blood.

#### CHORIONIC VESICLE.

The chorionic vesicle (the "ovum" of some writers) is slightly smaller than the "implantation cavity" in which it lies, and closely conforms to it in shape, measuring 8.5 mm. in its long axis, 7.7 mm. in width, and 4 mm. in depth (see Table I.). These measurements include the villi.

The external surface is partially covered with villi, which are very numerous on the aspect towards the decidua basalis and marginalis, but few and scanty on the aspect towards the decidua capsularis.

The villi were reconstructed on a portion of the wall at the junction of the decidua basalis and marginalis, where they were very numerous; an area of  $6\frac{1}{2}$  square mm. was found to have 30 to 40 villi of varying length, each of these measuring as much as .9 of a millimetre in length.

The Eternod ovum (Vuill) in a fresh condition measured, with its villi,  $10.0 \times 8.2 \times 6$  mm. Its villi had a length of 1.2 to 2 mm., their diameter being .3 to .8 mm., and it was expelled six days from the omitted period.

*Structure of the Chorionic Wall and Villi.*—The chorionic wall and villi showed the structure characteristic of this stage of development.

The most external layer consisted of a multi-nucleated layer of protoplasm, distinctly syncytial in character. At the tips of many of the villi this layer was increased in thickness, and formed a sort of knob, composed of a mass of syncytial tissue.

There was, in many places, a deeper layer of cells, the Langhans layer; but, except in a few places, the distinction between the syncytial and the Langhans layer was not clear. Underneath the cellular layer the chorion wall was composed of a loose reticular mesenchyme tissue with elongated spindle-shaped nuclei. This layer was thicker than the epithelial wall, and

<sup>1</sup> Nitabuch, R., *Beiträge zur Kenntniss der menschlichen Placenta*, Dissert., Bern, 1887.

its deeper surface was connected with a loose, fibrinous-like reticulum which occupied the interior of the chorionic vesicle and passed from the wall to the surface of the yolk-sac and of the amnion (figs. 1 and 2). This reticulum cannot be said to be organised tissue, and has much greater resemblance

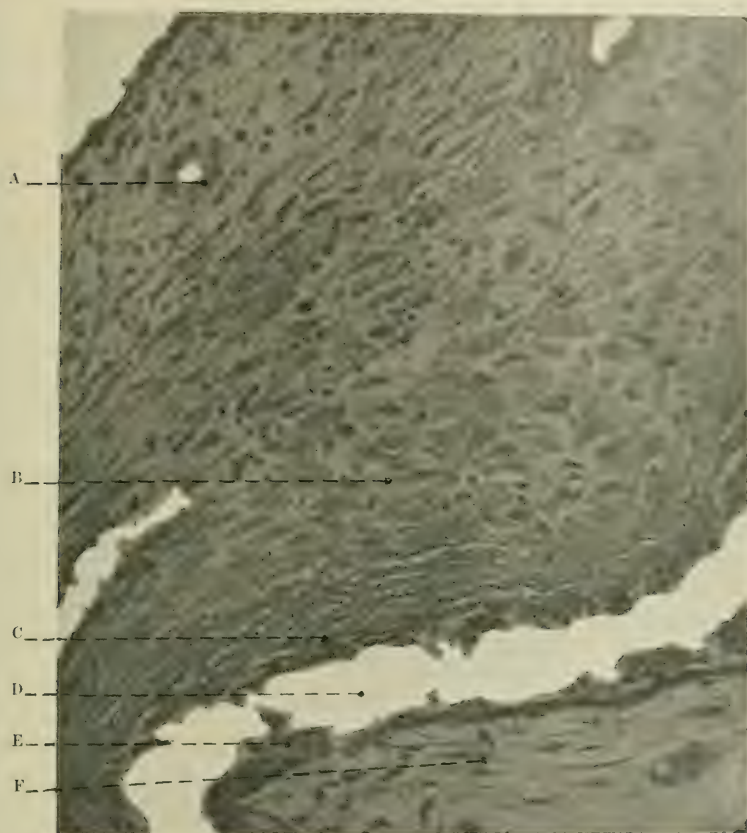


FIG. 2.—Section of decidua and chorionic wall.

A, deeper layer of decidua; B, decidual cells; C, fibrin stria; D, intervillous space;  
E, epithelial layer of chorion; F, chorionic mesoderm.

to a precipitation deposit. An area by the side of the vitello-intestinal junction in which this reticulum was absent represents a clear portion of the extra embryonic coelom.

The villi consisted of a core of loose mesenchyme tissue, in which blood spaces were present, and a covering cellular layer, similar to that of the chorion, but more distinctly two-layered.



## AMNION AND BODY STALK.

The same figure (fig. 1) shows also the stage of development of the amnion and the body stalk.

The former was a thin membrane, consisting of an inner layer of flattened epithelial cells and an outer mesenchymal layer. It invested only the dorsal aspect of the body stalk, leaving its ventral surface free in the chorionic cavity. In the ventral direction, the amniotic cavity was only very slightly longer than the embryo (see fig. 3).

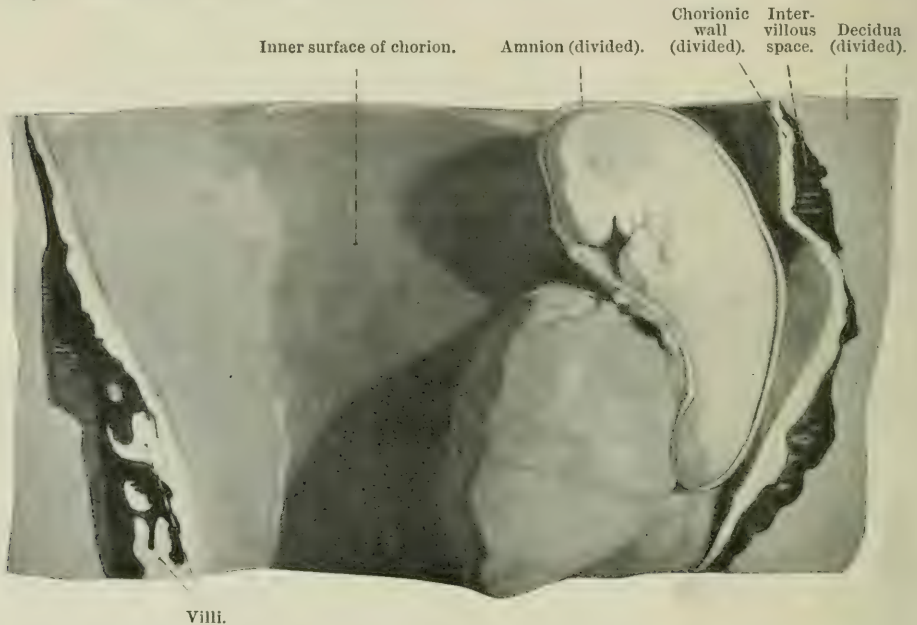


FIG. 3.—Reconstruction model, after removal of decidua capsularis and subjacent chorionic wall, showing embryo, etc., *in situ*. The investing amnion has been removed from this surface of the embryo.

The body stalk came off from the right side of the embryo and extended from the lower part of the heart region to the tail bend. It consisted of a loose tissue in which lay the large and tortuous umbilical vessels.

## EXTERNAL FORM OF THE EMBRYO.

The external form of the embryo is seen in fig. 3. That illustration shows that it is coiled in a slight spiral, the head lying to the right and the tail to the left.

There is a well-marked vertex bend as the anterior portion of the head

is bent down towards the heart, but there is no distinct nape bend, and the dorsal aspect shows merely a uniform curvature and passes into a short rounded tail process.

The lateral surface of the head shows a prominence overlying the otic vesicle, and in front of that there is another elevated area which marks the position of the developing trigeminal nerve.

The anterior and posterior neuropores are closed.

Behind the mouth orifice there are on each side three well-marked

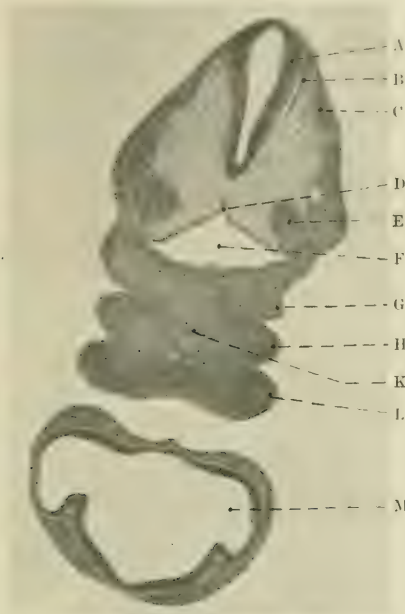


FIG. 4.—T.S. of head end of embryo.

A, neural tube; B, neural crest; C, somite; D, notochord in pharyngeal wall; E, anterior cardinal vein; F, pharynx; G, H and L, pharyngeal arches; K, thyroglossal duct; M, optic pouch.

elevations corresponding to the three anterior branchial arches, and behind the first and second of these there is a distinct cleft-like external pocket (fig. 4).

The groove behind the third arch is shallow, and in one or two sections the most dorsal part of this groove shows in its floor two slight elevations, which are the rudiments of the fourth and fifth arches (fig. 4).

Behind the third groove is an elevation which is due to the anterior cardinal vein.

The heart forms a distinct prominence on the ventral aspect of the

trunk, and the contours of its principal chambers are evident on the surface.

The body stalk passes to the right side, and the vitello-intestinal connexion towards the left, and the yolk-sac itself was bent to the left side and lay on the left side of the tail at its lower part.

The limb-buds have not appeared, but on the caudal portion of the trunk the Wolffian ridges were distinct. There were twenty-seven pairs of somites, and the dimensions of the embryo and yolk-sac are shown in the accompanying table.

TABLE SHOWING DIMENSIONS IN MILLIMETRES OF THE SPECIMEN DESCRIBED HERE, AND OF OUR COMPARISON WITH AN EARLIER AND A LATER SPECIMEN.

	Eternod (Vuill).	His, Embryo M.	2 W.1.
Implantation cavity . . . .	...	...	$9 \times 8 \times 4.1$
Chorionic vesicle . . . .	$10 \times 8.2 \times 6$	$7.5$ to $8$	$8.5 \times 7.7 \times 4$
Embryo { length (max.) . . . .	$1.3$	$2.6$	$2.9$
{ transverse . . . .	...	...	$0.9$
Yolk-sac { length . . . .	...	$2.6$	$2.6$
{ dorso-ventral . . . .	...	$1.7$	$2.0$
{ transverse . . . .	...	...	$1.6$

In its size and in the stage of development this embryo comes into the known series of human embryos at a stage not well represented.

It is slightly older than the embryo of Robert Meyer, No. 300 (N.T. vii.), which was described and figured by Thompson in this Journal,<sup>1</sup> and whose blood-vessels have been worked out and described by Felix.<sup>2</sup>

Another embryo which bears perhaps an even closer resemblance is embryo Wolff 2 of the Berlin Anatom.-biolog. Institut (Professor O. Hertwig), N.T. fig. vii. 5, which was obtained in a decidual cast of the uterine mucosa. The profile outline of my specimen is relatively longer in the long axis and shorter in the dorso-ventral diameter than that specimen, which measures 3.7 mm. in maximum length, and has 23 pairs of somites and 3 pharyngeal pockets.

Beyond the brief description of that embryo in the Normaltafeln, I have not been able to discover any complete account of the internal structure, and none appears to have been published.

Other embryos which resemble the present one are No. IX. of the Normaltafeln, belonging to the collection of Professor Hammar of Upsala,

<sup>1</sup> Thompson, *Jour. of Anat. and Phys.*, vol. xli., 1907.

<sup>2</sup> Felix, *Morph. Jahrbuch*, Bd. xli. Heft iv.

the greatest length of which was 3.4 mm. after fixation, and which had 28 pairs of somites: and another embryo of 3 mm. length described by Broman and figured in the text of the *Normaltafeln* (text-fig. 10), which has a distinct resemblance to the present specimen in regard to several details.

#### AGE OF THE EMBRYO.

The history of the decidual cast being passed 10 days after a missed menstrual period refers, I understand, to the anticipated commencement of the period, and therefore presumably some 34 days from the end of the last menstruation.

According to our present knowledge, the age of the embryo would therefore be estimated as from 16 to 19 days; but obviously this is an underestimate, and fertilisation must have occurred somewhat earlier in the intermenstrual period, and the age of the embryo is more probably nearer 30 days.

The stage of development can be estimated by reference to the stage of development of the heart rather than to the length of the embryo,<sup>1</sup> and on that criterion the present specimen is slightly older than the Meyer embryo 300.

#### INTERNAL STRUCTURE.

*Alimentary Canal* (fig. 5).—The bucco-pharyngeal membrane had ruptured, but the remains of it were present around the margins of the buccal orifice. That orifice was bounded by the forebrain anteriorly and the mandibular arches on each side and below.

From the anterior portion of the buccal depression Rathke's pocket projected towards the ventral aspect of the forebrain in the form of a blind recess, triangular on horizontal section, the apex of which passed towards but did not reach the forebrain (fig. 6).

The anterior end of the notochord terminated in the tissues forming the dorsal wall of this pocket (fig. 5).

There was no distinct indication of the presence of any projection of the roof of the pharyngeal cavity behind Rathke's pocket, and it may therefore be stated that Seessel's pocket was not present.

#### PHARYNX AND ALIMENTARY CANAL.

The three anterior branchial arches were present, and projected into the interior of the cavity of the pharynx, and the arches of the opposite sides met in the floor of the cavity. In that region behind the first arch there

<sup>1</sup> Mall, F. P., *Anat. Anz.*, Bd. xlv.



was the tubular growth of the thyroglossal duct, which extended downwards and terminated blindly on the ventral aspect of the conus arteriosus.

Near its termination a large round mass of cells lay on the ventral aspect of the duct, the cells in the interior being loosely packed together, while the peripheral ones formed a continuous wall. This mass of cells

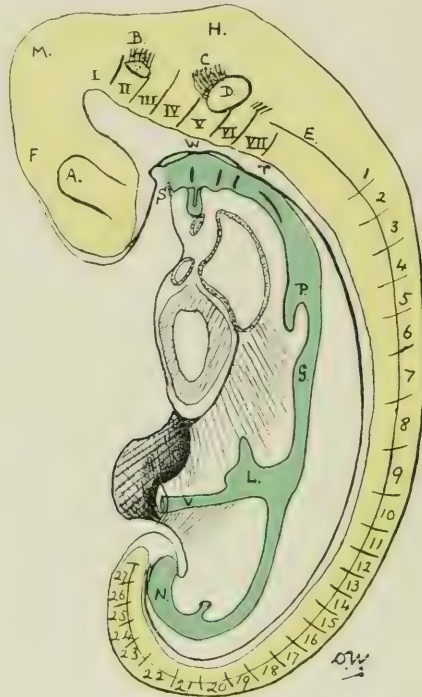


FIG. 5.—Linear reconstruction of nervous system, alimentary canal, etc.  
The figures 1–27 indicate somites, I–VII. neuromeres.

A, optic diverticulum; B, trigeminal nerve and ganglion rudiment; C, acustico-facial nerve complex; D, otic vesicle; E, neural crest; F, forebrain; G, stomach; H, hindbrain; L, liver-bud; M, midbrain; N, cloaca; P, above lung-bud; S, stomatodeum; T and W, notochord in contact with pharyngeal wall.

appeared to be connected with the thyroglossal duct, and not with any other structure (fig. 4).

Three internal pharyngeal pouches were present in the form of narrow slit-like clefts. Behind the third cleft the cavity dilated transversely in the form of a wide flange-like lateral expansion. This appears to be the rudiment from which the fourth and fifth internal pharyngeal pouches are derived later.

Caudal to this dilatation the lumen contracted and became altered in

shape. It was flattened from side to side, and the lining epithelium of the dorsal and ventral walls become different, that on the ventral aspect being long and columnar, while that of the dorsal half remained short and rather flat (fig. 12).

Still lower the tube became constricted about its middle, and shortly afterwards divided into a short ventral median lung-bud and oesophagus.

The median dorsal pharyngeal wall behind the level of the third pouch was found to be still in connexion with the notochord. At that level there



FIG. 6.—T.S. head<sup>2</sup>end of embryo.

A, forebrain; B, optic vesicle; C, Rathke's pouch; D, olfactory area; E, bucco-pharyngeal membrane; F, artery in pharyngeal arch; G, dorsal recess on pharyngeal wall.

was a small median cleft-like recess lined with epithelial cells, which extended for a short distance dorsally in the posterior part of the roof of the pharynx. The notochord was found to be connected with the cells lining the caudal part of this recess, and it was absent along the whole length of the recess. At this level apparently the notochord is late in being folded off from the endothelium of the vitello-intestinal cavity. This observation is in harmony with, and to some extent explains, the results obtained by Huber<sup>1</sup> in his examination of the development of the pharyngeal bursa, for this region coincides with an area of the pharyngeal wall in which, in embryos of 5–8 mm. length, the notochord is found in close contact with the pharyngeal endoderm, representing the seat of development of the

<sup>1</sup> Huber, G. C., *Anat. Record.*, vol. vi.

pharyngeal bursa. It also confirms Meyer's<sup>1</sup> observations on the occasional persistence of a connexion between the chorda and the pharyngeal entoderm.

A short distance caudal to the origin of the lung-bud the lumen of the foregut showed a slight dorso-ventral dilatation, marking the position of the stomach, and a short distance beyond this level the vitello-intestinal junction was found. The liver-bud was present as a tubular diverticulum arising from the proximal portion of a groove on the ventral or cephalic

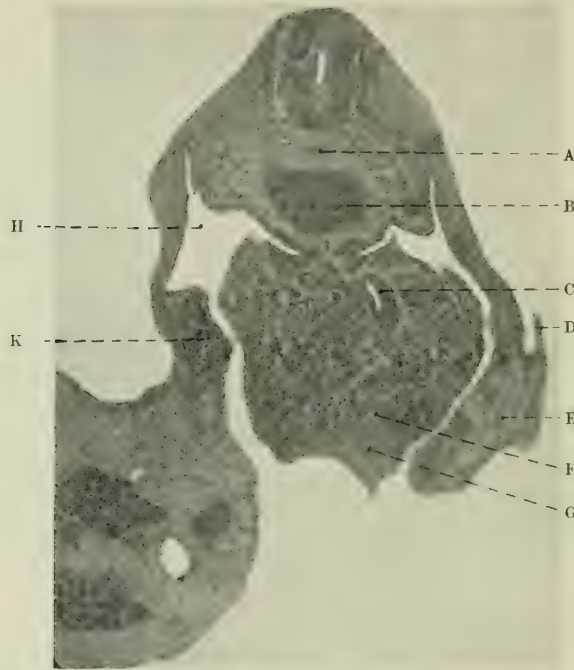


FIG. 7.—T.S. at level of liver bud.

A, notochord; B, united dorsal aortae; C, intestine; D, amnion; E, umbilical vein; F, liver-bud; G, septum transversum; H, coelomic cavity; K, right umbilical vein.

aspect of the stalk of connexion. The hollow tubular pocket passed for a short distance in the substance of the septum transversum, in close relation to the vessels of that septum, and these vessels for the greater part lay dorsally to it. There was no trabecular formation as yet, nor was there any indication of a pancreatic diverticulum (fig. 7).

The hindgut formed a tubular and for the most part cylindrical entodermal tube, and terminated in the dilatation of the cloaca (fig. 5).

<sup>1</sup> Meyer, R., *Anat. Anz.*, vol. xxxvii.

Over a considerable extent the mesodermal wall of the hindgut showed a trefoil appearance on section, produced by a surface depression on the ventral and on each lateral aspect near the root of the mesentery. This appearance was due rather to the prominence of vessels in the intervening areas than to any constriction of the wall.

The allantois arose from the ventral aspect of the hindgut at the upper part of the cloaca, but could not be traced for any distance into the body stalk.

The lumen of the distal part of the cloaca ventrally is separated from the surface merely by its layer of lining entodermal cells and by the investing ectoderm, the cloacal membrane.

Its lumen is compressed from side to side, but is of some size in a dorso-ventral direction (fig. 9).

The terminal parts of the Wolffian ducts end blindly on each side of it.

#### RESPIRATORY SYSTEM (fig. 12).

The stage of development of the respiratory system shows the lung-bud as a median, short, somewhat cylindrical outgrowth from the lower part of the pharynx.

It resembles the condition figured and described in an embryo 4.25 mm. vertex breech length (R. Meyer, No. 399), the principal difference being that in my specimen the median unpaired lung-bud is somewhat longer than in that specimen (fig. 12).

It arose from the ventral aspect of the floor of the pharynx, the lumen taking origin in a long narrow groove which occupied the floor of the pharynx immediately above the level at which the lung-bud becomes free.

It lay ventral and parallel to the upper part of the oesophagus, and the upper part was cylindrical in outline. Lower down it became widened in the transverse axis, and terminated in a knob-like enlargement, flattened dorso-ventrally, the lateral expansions forming the only indication of the origin of the paired lung-buds from the median unpaired original outgrowth.

There were no pulmonary arteries, but two pulmonary veins arose from a small plexus about the lower part of the respiratory outgrowth and passed independently of the other venous channels of the body into the atrium of the heart just on the atrial side of the sinu-atrial junction.

#### VASCULAR SYSTEM—ARTERIES.

The arterial vessels are shown in fig. 13.

From the heart a short conus arteriosus passed towards the floor of the pharynx, and divided into right and left branches, from which the branchial arch vessels of the two sides arose.



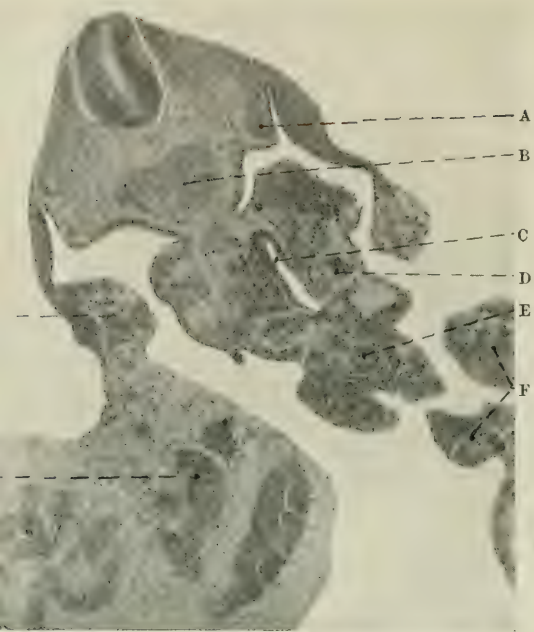


FIG. 8.—T.S. cranial to vitello-intestinal junction.

A, Wolffian tubule; B, united dorsal aortæ; C, intestine; D, vitelline vessels; E, liver-bud; F, vitelline vessels in yolk-sac; G, right umbilical in; H, umbilical vessels in body stalk.

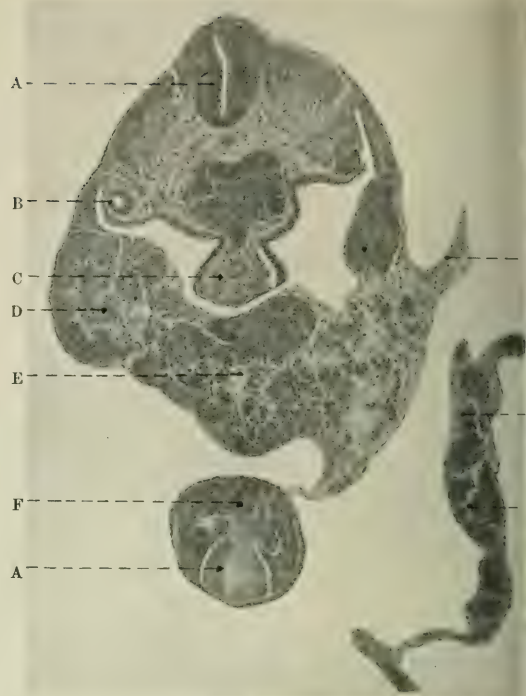


FIG. 9.—T.S. caudal to fig. 8.

A, neural tube; B, Wolffian duct; C, mesoderm round intestine; D, right umbilical vein; E, umbilical arteries; F, cloaca; amnion (cut); H, vessels in yolk-sac.

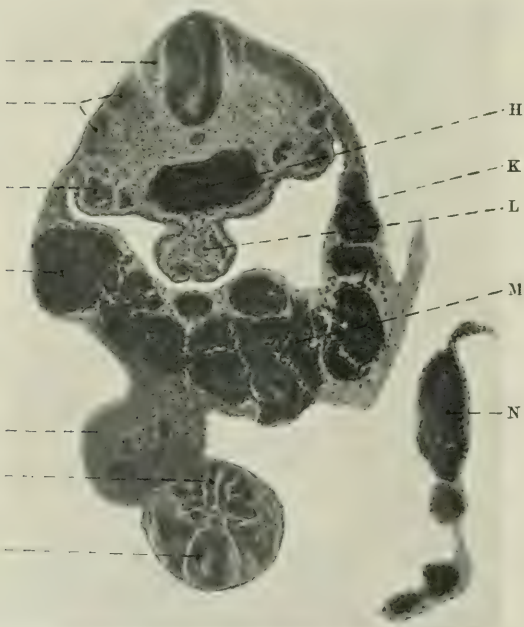


FIG. 10.—T.S. caudal to fig. 9.

A, neural crest; B, somites; C, Wolffian duct; D, right umbilical vein; E, mesoderm connecting trunk and tail; F, cloaca; G, neural tube; H, aorta; K, left umbilical vein; L, intestine; M, umbilical vessels; N, yolk-sac.

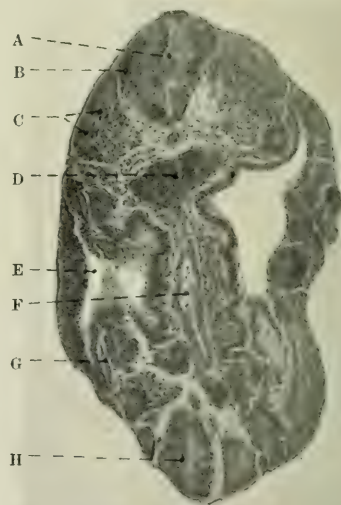


FIG. 11.—T.S. at level of tail bend.

A, neural tube in trunk; B, neural crest; C, somites; D, dorsal aorta; E, coelom; F, intestine and allantois; G, Wolffian duct; H, neural tube.

A rudimentary and incomplete first arch entered the tissue of the first arch, but did not reach the dorsal end of that arch.

In both the second and third arches a short wide vessel was present, and passed dorsally to join the head dorsal aorta.

This dorsal stem was prolonged forwards towards the root of the optic vesicle, and there divided. The posterior branch passed dorsally in the concavity of the cephalic flexure and extended backwards to the midbrain.

Short vessels passed from it to the neural tube, and in the region of the neuromeres these branches were arranged segmentally, one vessel running in each of the surface grooves which separated the neuromere segments from one another.

The grooves between the 4th, 5th, and 6th segments were occupied by two short vessels which appeared to be branches of the dorsal aorta, one



FIG. 12.—Reconstruction of lower end of pharynx, lung-bud, and upper part of œsophagus.

arising on the cranial and the other on the caudal side of the junction of the third arterial arch. These vessels did not communicate with one another. This stage of development of the cephalic and cerebral blood-vessels forms a stage intermediate between the one existing in the embryo of 23 somites described by Felix, and that shown in Ingall's reconstruction of the head vessels in an embryo of 4.9 mm. long, both of which are figured in the Keibel-Mall *Manual*, vol. ii. pp. 602 and 606.

In the former the first and second arches were complete, but there were no prolongation forwards dorsally to the forebrain, nor any branches to the mid and hind brains. In the latter there were four complete arches, whose dorsal ends are united, and there was also a cerebral blood-supply from a primitive internal carotid and vertebral artery.

The dorsal aortæ united opposite the sixth somite, and passed thence almost to the end of the neural tube. The branches which arose from the aortæ were somewhat irregular in their arrangement.

This may possibly be due to some vessels having been omitted or

overlooked through their not containing any blood-cells, but against this is the fact that the vessels were everywhere packed full of blood-cells, which rendered their recognition easy, even though the lumen of some of the branches was large enough only to contain a single blood-cell. Segmental dorsal offshoots were found in the region of the 5th, 6th, 7th, and 8th somites, but a connexion between them and the aorta could not be followed out.

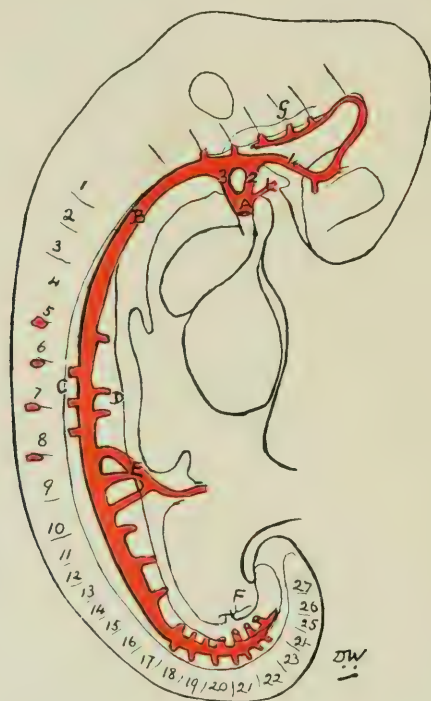


FIG. 13.—Linear profile reconstruction of arteries.

A, conus arteriosus; B, dorsal aorta; C, dorsal segmental vessels; D, ventral segmental vessels; E, vitelline rootlets; F, umbilical rootlets; G, segmental vessels to hindbrain.

There were also occasional lateral branches passing to the region of the Wolffian body, arranged somewhat irregularly.

There was a definite series of vessels passing to the intestinal tube. These vessels can be arranged in groups, consisting of a set arising from the aorta in the region of the 5th, 6th, 7th, and 8th somites, which went to the region of the gastric enlargement, while behind them the vitelline arteries arose by a series of rootlets three in number, which united to form a single vessel on each side.

Still further back, a series of ventral branches passed to the region of the hindgut, while in the region of the tail bend the aorta terminated in the manner described by Evans in a plexus of capillary-like vessels (the ventral arch system of Felix), from the lower of which the umbilical arteries arose by multiple roots, while from the dorsal aspect of the plexus

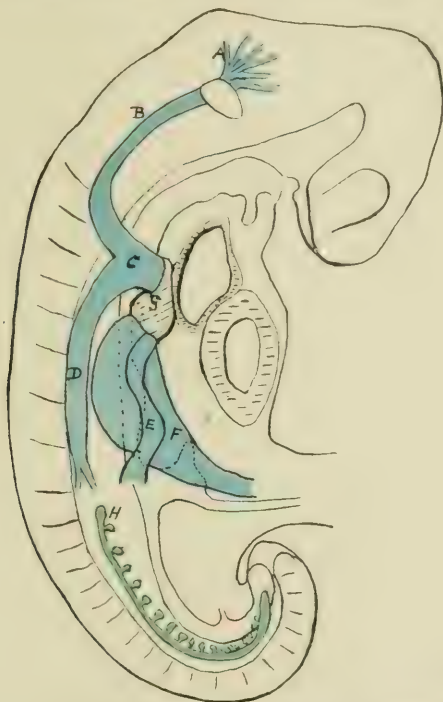


FIG. 14.—Linear reconstruction of veins and of excretory system.

A, anterior cardinal rootlets (*vena capitis medialis*); B, anterior cardinal;  
C, duct of Cuvier; D, posterior cardinal vein; E, umbilical vein;  
F, vitelline vein in septum transversum; G, sinus venosus; H, excretory system.

a series of dorsal segmental arteries passed towards the back, and occupied the intervals between the somites of this region.

#### VEINS (fig. 14).

In the region of the hindbrain, an extensive capillary network gave origin to a vessel of some size, the *vena capitis medialis*, lying between the otic vesicle and the brain. This vessel continued downwards, received irregular tributaries, and passed onwards in the segmental area as the anterior cardinal vein.



The duct of Cuvier was formed in the lateral body wall at the level of the 3rd somite, and passed to the upper margin of the septum transversum.

The posterior cardinal vein could be traced as far back as to the lower part of the 9th somite, or, in other words, as far as the upper end of the mesonephric duct. Below that level there was some indication of a few capillary-like vessels in the position of the subcardinal vein.

The right and left umbilical veins passed at the junction of body wall and amnion and turned medially to join the upper lateral part of the septum transversum, and to the right and left extremities of the sinus venosus respectively. The vitelline veins were of very large size.

In the lower part of the septum transversum they fused with one another, forming a single large vessel lying on the ventral aspect of the intestine, and above that level they separated and terminated, close to one another, in the transverse part of the sinus venosus.

#### NERVOUS SYSTEM.

*Central Nervous System.*—There was no histological differentiation of the wall of the neural tube by which its different segments could be separated from one another, nor were there any definite constrictions limiting the different parts of the cerebral region.

It is, however, clear that the midbrain occupied the region of the cephalic bend, and it passed anteriorly into the forebrain, with which are associated the optic vesicles, and posteriorly into the hindbrain, which has certain structural characters by which it can be identified. The hindbrain was somewhat dilated, and its neural wall was incomplete dorsally in part.

The hindbrain merged in turn into the spinal portion of the neural tube.

The hindbrain showed transverse segmentation (fig. 15) in the form of bilateral and symmetrical constrictions of the external surface, represented by elevations on the inner aspect, these elevations separating from one another the rhombic grooves. In the intervals between the surface constrictions the wall was thickened, and thus the internal segmentation was less obvious than that of the external surface. Seven such segments were present, extending from the region of the cephalic flexure backwards; and certain of these segments had a distinct relationship especially to the origin of the trigeminal nerve, to the acoustic nerve, and to the otic vesicle, as is indicated in the figure.

The relationship of the surface constrictions to the blood-vessels has been pointed out, but the segmentation is not due to these vessels, since the actual thickness of the wall is different in the segments and in the intervals.

The number and arrangement of the segments correspond closely to those figured and described by Thompson in the 2.5 mm. embryo already referred to, and it need only be added here that the trigeminal nerve was associated with the 2nd anterior segment, the acoustic nerve with the 4th, while the otic vesicle lay opposite the 5th segment.

*Spinal Cord.*—The structure of the spinal cord showed no features requiring special description, since it was typical of this stage. There was no indication of the outgrowth of spinal nerves.

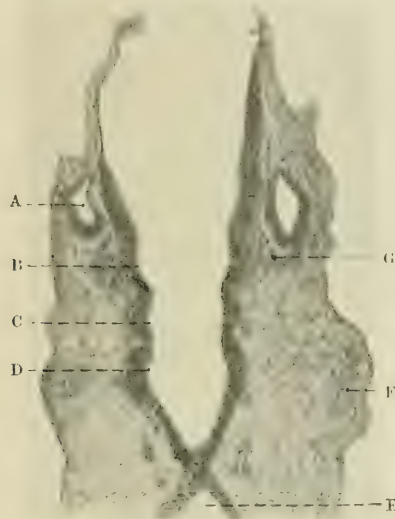


FIG. 15.—T. S. through otic vesicles and hindbrain.

A, otic vesicle; B, C, and D, 4th, 3rd, and 2nd neuromeres; E, cavity of forebrain; F, trigeminal ganglion; G, acustico-facial ganglion.

*Neural Crest.*—The neural crest extended from the tail region as far forwards as to the last neuromere of the hindbrain in an unbroken band.

In section it had the form of a triangular narrow lamina, lying between the dorsal portion of the neural tube and the mesial border of the somites. This lamina showed a slight amount of segmentation alternating with the mesodermic somites. As is seen in the figure, it did not extend as far forwards as to the otic vesicle.

#### ORGANS OF SPECIAL SENSE.

The special-sense organs which had made their appearance were the olfactory, the optic, and the auditory.

*Olfactory Organ.*—An early stage of the development of the olfactory

organ was represented by a thickening of the surface of the epithelium immediately ventral to the root of the optic vesicles.

This thickened epithelium occupied a shallow spherical dimple on the surface of the side of the head, but no nerve connexion between it and the neural tube was present (fig. 6).

*Optic Vesicles.*—The position, shape, and form of the optic vesicles are shown in figs. 5 and 6. They arose from the ventro-lateral aspect of the fore-brain, and formed two large hollow vesicles, which projected dorso-laterally and lay almost in contact with the surface of the forebrain, and gradually separated from it. There was no definite stalk of connexion, but their base was constricted near the point of the attachment. The cavity of the fore-brain was in free communication by a large aperture on each side with the cavity of each of the vesicles (fig. 4).

There was no indication of the formation of the lens, but the lateral surface of each of the vesicles was indented, and a slight groove ran from this hollow towards the region of attachment to the brain, constituting an early stage of the choroidal fissure.

*Otic Vesicles.*—These two vesicles are shown in section in fig. 15. They formed on each side an oval hollow structure, whose communication with the surface of the head is closed, a narrow stalk passing from the dorsal part of the vesicle towards the surface, but not opening upon it.

#### CRANIAL NERVES.

*Trigeminal.*—The position of the trigeminal rudiment is indicated by an elevation on the lateral surface of the head, a short distance rostral to the elevation produced by the otic vesicle. The area was irregularly oval in shape, and was due to an area of marked proliferation in the epithelium and subjacent mesenchymal tissue. The general characters of this area are shown in fig. 15.

Sections dorsal to this level show that the dorsal aspect of this area is connected by a column of deeply staining cells with the surface of the 2nd neuromere.

Fig. 5 gives a diagrammatic representation of the surface area and its connexion, and brings out the fact that there is a definite placode-like formation in connexion with the early development of the trigeminal nerve.

The proliferative area and the cellular strand appear to be similar to the so-called "epibranchial proganglion" and the "pronerve," described and figured by Giglio-Ios in a human embryo of the seventeenth day.

*Acustico-facial Nerve.*—This nerve complex was present as a cellular

band passing from the rostral border of the otic vesicle to the 4th neuromere of the hindbrain, and it is shown in figs. 5 and 15.

*Vagus and Glossopharyngeal.*—The rudiments of these nerves were not so fully developed as the two former. The only traces found consisted of a thin cellular strand connected with the hindbrain behind the 5th neuromere, and passing towards the surface.

This strand resembled a portion of the neural crest, but was situated above the cephalic end of that structure.

#### EXCRETORY SYSTEM.

The excretory system consisted of the Wolffian duct and of a series of mesonephric tubules at different stages of development (figs. 8–11).

No pronephric tubules were present.

The Wolffian ducts began blindly at the level of the 9th somite, and passed towards the cloaca, where they terminated blindly, between the 25th and 26th segments. The first tubule lay at the level of the 10th somite, which may be taken to be the 6th cervical segment, and thus the condition corresponds with the observations of Felix, who has not found mesonephric tubules further forwards than this level.

The tubules were arranged irregularly, *e.g.* not segmentally, and were eighteen in number (fig. 14).

The anterior ones communicated with the duct, while the more posterior ones were free, and had not apparently established their connexion with it.

#### HEART.

A separate model was made, at a magnification of 200 diameters, of the heart, pericardium, and the adjacent segment of the trunk, from which the three figures appended have been drawn (figs. 17–19).

I have elsewhere<sup>1</sup> given a short account of some of the features of the heart in this embryo; but as Thompson's account of the heart in the R. Meyer embryo 300 is the only description of the heart at this stage, and as different interpretations have been put upon the appearances shown in his models, I have thought it advisable to give a more detailed account of it now.

It may be stated at once that in practically all its details the present specimen corroborates Thompson's account, and comparison with his figures shows the degree of resemblance between the two specimens.

The heart consists of sinus venosus, single atrium, atrial canal, and of an additional ventricular chamber, conical in shape, with two limbs: the

<sup>1</sup> Waterston, *Lancet*, May 1914.



proximal of these limbs is connected on the left with the atrial canal and forms quite clearly a ventricle, while the distal chamber is more tubular in form and leads cephalad to the short conus arteriosus.

This is the bulbus limb of the ventricular loop, and perhaps that term may be retained for descriptive purposes, without however committing us to the theory that this limb is to be taken to be the same as the bulbus

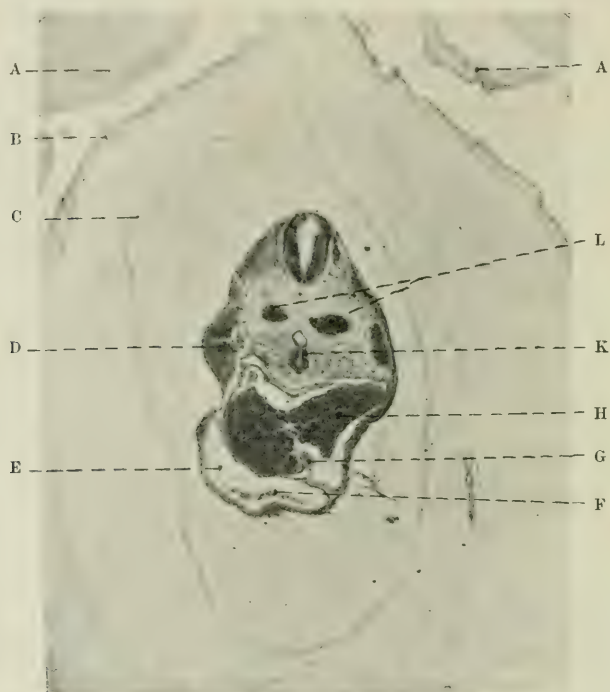


FIG. 16.—T.S. at level of heart.

A, decidua; B, chorion; C, amnion; D, anterior cardinal vein; E, reticulum in bulbus cordis; F, endothelial tube; G, atrial septum, incomplete; H, left portion of atrium; K, pharynx; L, dorsal aortae.

cordis of the reptilian heart. The angle at the junction of these two limbs constitutes the apex of the ventricular portion.

A long oblique groove separates the two limbs from one another, and it may be termed the bulbo-ventricular groove. The heart described by Thompson shows what I take to be a similar condition of the ventricular portion of the heart, the principal difference being that the bulbo-ventricular groove in his specimen runs almost horizontally, and that therefore the "ventricular loop" is caudal in position and the "bulbus" loop cephalic to it.

There is evidence that the bulbo-ventricular groove ontogenetically becomes more and more oblique, and is eventually almost vertical in direction, and I take it that this difference between the two specimens means that the former one is at a slightly earlier stage than the one described here.

The conus arteriosus is a short stem which soon divides into branches, as has been described earlier.

*Sinus venosus*.—The sinu-atrial junction is placed on the right side of the heart, and the terminal portion of the sinus venosus is in continuity

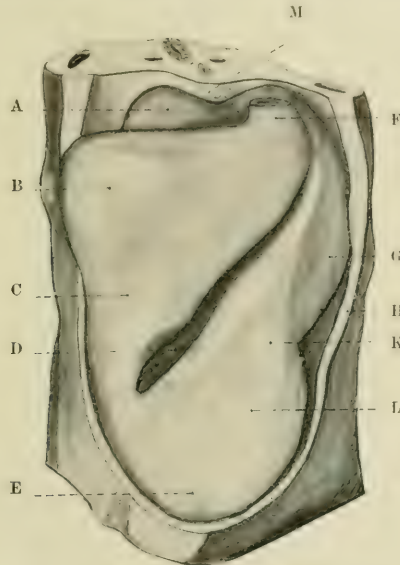


FIG. 17.—Wax-plate reconstruction of heart and coadjacent part of trunk.

A, upper part of atrium; B, dilatation of bulbus limb; C, bulbus; D, bulbo-ventricular groove; E, apex of ventricle; F, ventricular limb; G, atrio-ventricular canal; H, body (pericardial) wall; K, atrium; L, conus arteriosus; M, dorsal mesocardium.

with the atrium. The remainder of the sinus venosus is placed in the upper part of the septum transversum, and is seen in fig. 19 as it passes in the septum across to the left side. The right end received the right duct of Cuvier and the right umbilical vein, and the left end the corresponding vessels of the left side, while the right and left vitelline vessels opened into the cross piece.

The sinu-atrial junction was a narrow, vertical, slit-like orifice, and there was an infolding of the junction of the two chambers on the right of the orifice, forming a right venous valve. There was no indication of the left venous valve at this stage.

*Atrium.*—This constituted the dorsal and cephalic portion of the heart, and projected on each side, but mainly to the left.

Its ventral wall was grooved by the bulbo-ventricular groove, and the infolding of the wall produced thus constitutes a rudiment of the septum primum of the atrium, most distinct on the ventral wall of that chamber and passing on to the floor and the roof. The myocardial and the endothelial walls were in apposition with one another in these two chambers for the greater part, but became separated as the atrial canal is approached. Between these walls in the other chambers of the heart is seen the delicate reticulum which has been shown to occur in other specimens about this

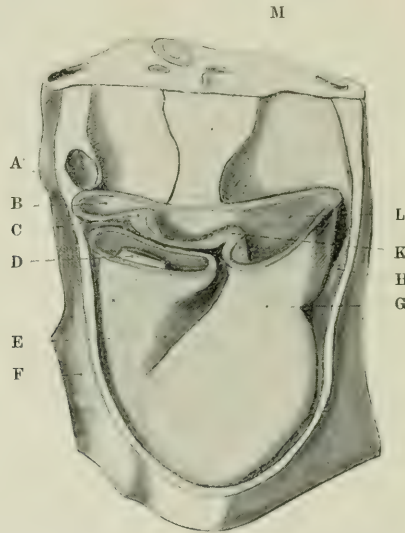


FIG. 18.—The model in fig. 17, the heart divided horizontally.

A, duct of Cuvier; B, sinus venosus; C, right venous valve; D, endothelial tube in bulbus; E, bulbo-ventricular groove; F, body wall; G, atrial canal; H, left duct of Cuvier; K, infolding of atrial wall (septum primum); L, left portion of atrium; M, dorsal mesocardium.

stage<sup>1</sup> (see Atrial Canal). The position and size of the endothelial channel are shown in figs. 16 and 18, which show that there is a very narrow endothelial tube, separated from the myocardial wall by a wide delicate reticulum. The ventricular limb of the ventricle had a myocardial wall of moderate thickness, which showed trabeculae on its inner surface. The bulbo-ventricular groove caused a slight infolding of the wall by which the two limbs are separated as by a partial septum on the ventral aspect, and the ridge constituted a partial bulbo-ventricular septum.

<sup>1</sup> Mall, F. P., *Am. Jour. of Anat.*, vol. xiii. p. 249.

The ascending or "bulbus" limb passed first headwards and then horizontally to the left.

At the junction of the two parts was a marked dilatation of the myo-epicardial wall.

The myo-epicardial and endothelial walls were widely separated from one another in the whole length of the "bulbus" limb. The interval between the two is shown in fig. 16 as a space, which, however, is occupied by a delicate reticulum, as is seen in the section reproduced here (fig. 16).

The significance and the homologies of the bulbus limb cannot be discussed without reference to older specimens, and I do not propose to go into that question here.

#### CÆLOM.

The intra-embryonic and the extra-embryonic divisions of the cœlom communicated with one another freely by the opening on each side of the vitello-intestinal connexion, between it and the body wall (fig. 1). The characters of the latter division have been described with the chorionic vesicle.

The intra-embryonic cœlom may be conveniently described under the divisions which it presents into pericardial sac, peritoneal sac, and the peritoneo-pericardial communications, which connect the two former.

The dorsal wall of these portions of the body cavity is shown in fig. 20. There was a median continuous mesentery, and the extent of its attachment is shown in that figure. The cephalic portion constitutes the dorsal mesocardium, and below the level of the heart the mesentery was attached to the dorsal surface of the septum transversum, and thus formed the ventral enteric mesentery. In using the term "mesentery" at this stage, it must be pointed out that there is no proper mesentery, for the alimentary canal lies embedded in the trunk of the embryo (fig. 9), and this mesenteric structure is merely a connexion between the dorsal wall of the embryo on the one hand and the heart and septum transversum ventrally.

The body wall on each side contain the ducts of Cuvier, which passed to the septum transversum, and the level of these two vessels gives the level of the upper margin of the septum transversum, whose cephalic surface constitutes the floor of the pericardial cavity.

The dorsal wall of the cœlom showed a rounded bulging projection on each side of the mesenteric root. There can be no doubt that these bulgings represent the mesodermal elements of the lungs, which are already being formed as a thickening of mesenchymal tissue, which is later penetrated by the growing hypoblastic tubes, but the epithelial lung-bud does not descend as yet to their level.



The pericardio-peritoneal communication is even at this stage being narrowed by these thickenings, which lay at a lower level than the upper margin of the septum transversum.

The figure (20) also shows the narrow orifices of the pneumato-enteric recesses.

These diverticula from the intra-embryonic coelom were present on both sides, as they were in the 3 mm. embryo in which they have been found

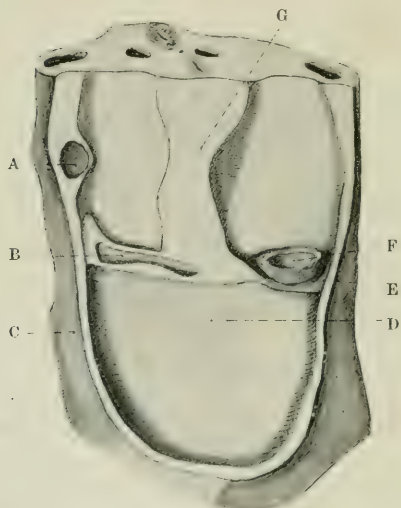


FIG. 19.—The model in fig. 17, after removal of the heart.

A, Right duct of Cuvier; B, sinus venosus; C, body wall; D, floor of pericardium (septum transversum); E, left duct of Cuvier; F, left portion of atrium; G, dorsal mesocardium. The pericardio-peritoneal connexions lie behind B and medial to F respectively.

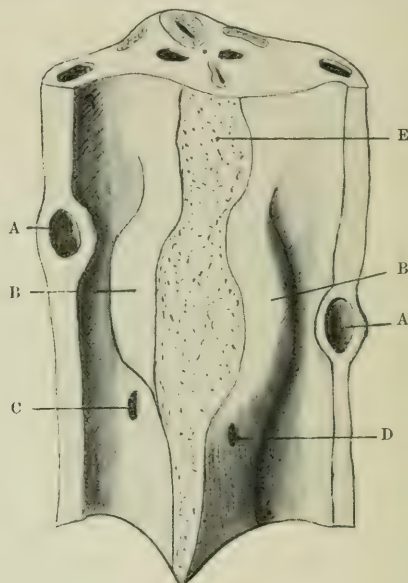


FIG. 20.—The model in fig. 19, after removal of the septum transversum, showing the dorsal wall of pericardial and peritoneal coelom with orifices of right and left pneumato-enteric recesses. The dotted area indicates, above, the attachment of the dorsal mesocardium, and, below, the ventral mesentery.

A, ducts of Cuvier; B, mesodermal lung thickenings; orifices of pneumato-enteric recesses.

by Broman.<sup>1</sup> From each of the slit-like openings a pocket passed in a cephalic direction, tunnelling the body wall, and lying by the side of the alimentary canal.

Their lining membrane consisted of thickened coelomic epithelium. No special significance attaches to this fact of its being thicker here than elsewhere, as the coelomic epithelium tends to become thickened in regions where two surfaces are in contact.

<sup>1</sup> Broman, *Morph. Arbeiten*, Bd. v.

Caudal to the vitello-intestinal junction, the peritoneal coelom presented no features of special significance, and its general character is shown in the sections figured through that region of the embryo.

#### SEPTUM TRANSVERSUM.

The septum transversum at this stage lay very obliquely, in a dorso-ventral and cephalo-caudal axis.

I have included a figure (19) which shows its cephalic surface, forming the floor of the pericardium, and its lateral continuity with the body wall. This cephalic surface is flat; the caudal surface, on the other hand, presents on each side of the mesial plane a large dorsal swelling, produced by the vitelline veins. The shape resembles that of the liver, the prominent veins being apparently the forerunners of the subsequent right and left lobes.

#### SUMMARY OF CHARACTERS OF THE EMBRYO DESCRIBED ABOVE.

*Designation.*—2 W.I.

*Dimensions.*—Chorionic vesicle . . . . .  $8.5 \times 7.7 \times 4$  mm.

Length: Amniotic sac . . . . . 3 mm.

Embryo . . . . .  $2.9$  (max.)  $\times 1.2$  dorso-ventral  
 $\times .9$  mm. (transverse at heart).

Yolk-sac, . . . . .  $2.6 \times 2$  (dorso - ventral)  $\times 1.6$   
(transverse) mm.

*Age.*—Period elapsed since beginning of last menstruation to commencement of abortion, 42 days. Period elapsed since due date of lapsed menstruation, 10 days.

*Body Form.*—General uniform dorsal curvature and cephalic flexure. Slight spiral twisting. Blunted tail projection. Body stalk passes to the right side. Yolk-sac lies to the left.

*Mesodermal Somites.*—Twenty-seven pairs.

*Chorda.*—Almost completely formed, except in dorsal pharyngeal region, where it is not yet folded off. Terminates in dorsal wall of Rathke's pocket.

*Nervous System.*—Neural tube completely closed. Forebrain, mid and hind brain, the latter with seven neuromeres. Neural crest. Cranial nerves, trigeminal, and acustico-facial. Vago-glossopharyngeal rudimentary.

*Eye.*—Primary optic vesicles separated from surface ectoderm by mesenchyme. No lens plate.

*Ear*.—Otic vesicles embedded in mesenchyme near surface of hindbrain and unconnected with the surface ectoderm.

*Nose*.—Olfactory area present, as a rounded dimple, with thickened epithelium.

*Hypophysis*.—Dorsal pocket from buccal cavity.

*Mouth*.—Bucco-pharyngeal membrane ruptured.

*Alimentary Tract*.—Intestine connected with yolk-sac by very small channel. Liver-bud present; no pancreatic bud.

*Pharyngeal Pockets, etc*.—Three in number. Patent thyroglossal duct.

Lung-bud, median ventral offshoot from lower end of pharynx.

*Urogenital System*.—Wolffian duct present, but not connected with cloaca. Seventeen pairs of tubules. No pronephric structures.

*Heart and Vessels*.—Sinus venosus, single atrium, atrial canal, and ventricle with a left descending ventricular limb and right ascending "bulbus limb," leading to short conus arteriosus. Sinu-atrial junction with right venous valve. Continuous myo-epicardial wall. Endothelial tube widely separated from myo-epicardial wall in the "bulbus" limb, ventricular limb, and atrial canal. Incomplete first and complete second and third pharyngeal arterial arches and dorsal aortæ. Anterior cerebral artery. Dorsal segmental arteries and ventral segmental vessels to intestine, arranged irregularly.

*Amnion*.—Ectodermal and mesodermal layers. Invests dorsal aspect of body stalk.

*Allantois*.—Traced for a short distance from intestine.

*Remarks*.—Obtained in a decidual cast, passed 10 days after a missed menstrual period. Formalin fixation. Cut in paraffin. Histology on the whole is good. Neural tube somewhat shrunken. Mitotic figures visible.

*Literature*.—WADE AND WATSON, *Jour. of Obstetrics and Gynecol. Brit. Empire*, Feb. 1910.

# JOURNAL OF ANATOMY AND PHYSIOLOGY

A RECONSTRUCTION MODEL OF THE RIGHT MIDDLE AND INNER EAR. By J. S. FRASER, M.B., F.R.C.S. Edin., *Assistant Surgeon, Ear and Throat Department, Royal Infirmary, Edinburgh; Aural Surgeon to Leith Hospital; Lecturer on Diseases of the Nose, Throat, and Ear, School of Medicine of the Royal Colleges, Edinburgh*; and J. K. MILNE DICKIE, M.D., F.R.C.S. Edin., *Demonstrator of Anatomy, University of Edinburgh; Assistant Aural Surgeon, Leith Hospital*.

THE model illustrated in this paper was constructed primarily with the object of facilitating the teaching of the anatomy and physiology of the ear, and also to have before us an exact reproduction of an anatomical specimen.

## METHOD OF PREPARATION OF MICROSCOPIC SECTIONS OF THE PETROUS BONE.

(a) *Preparation of the Block of Bone containing the Middle and Inner Ear*.—As the preparation of microscopic sections of the temporal bone is a somewhat intricate and delicate process, the writers give a short account of the method employed. For a more detailed description the reader is referred to a paper by one of us (J. S. F.) in the *Journal of Laryngology, Rhinology, and Otology*, December 1913.

The temporal bone is obtained as soon as possible after death—certainly within twenty-four hours. The dura mater is divided round the internal auditory meatus, so that the nerves may not be pulled out when the dura mater is stripped from the bone to allow the fixing solution to soak in. The superior semicircular canal is opened with bone forceps to allow the fluid to enter the labyrinth. With the saw a cuboidal block, containing the more important parts of the middle and the whole of the inner ear, is now cut out from the temporal bone. The first saw cut is made in a



vertical direction at right angles to the long axis of the petrous pyramid just in front of the internal auditory meatus. The second saw cut is made parallel to and behind the first, through the mastoid antrum posterior to the semicircular canals. The third vertical saw cut is made in an antero-posterior direction through the middle cranial fossa and external auditory meatus, and runs parallel to the posterior surface of the petrous pyramid and to the middle ear cleft. The last cut is in a horizontal direction about a quarter of an inch below the internal auditory meatus, and passes through the jugular fossa.

In this way a six-sided block is obtained. The anterior wall of the external auditory meatus is now removed with bone forceps so as to expose the membrana tympani. The lining of the jugular bulb is stripped off and the anterior wall of the carotid canal is removed along with the internal carotid artery. The block is washed in running water for a minute or two to remove bone dust, and is afterwards fixed in 5 per cent. formaldehyde for one month, the fluid being changed on several occasions.

(b) *Decalcification, Washing, and Hardening*.—After fixation the specimen is kept in decalcifying fluid for six weeks in a wide-mouthed, glass-stoppered bottle. For decalcification Perenny's solution is recommended ( $\text{HNO}_3$  10 per cent., 400 c.c.; abs. alc., 300 c.c.; chromic acid, 0.5 per cent., 300 c.c.). During the first week the fluid is changed daily, during the second week every second day, and during the third and subsequent weeks the fluid is changed twice weekly. After decalcification, the block is washed in running water for five days, and is then carried through gradations of alcohol till it reaches absolute alcohol. Before embedding, it is placed in alcohol and ether (equal parts) for twenty-four hours.

(c) *Embedding*.—The block is placed in thin celloidin for one month, and then transferred to thick celloidin for one month. At the end of the second month the celloidin is allowed to harden. The specimen is finally mounted on a stabilite block and cut with the Schantze microtome.

(d) *Cutting and Staining*.—The specimen from which the model was made was cut in serial, vertical, transverse sections ( $30\mu$ ), and yielded about seven hundred sections. These were stained with Meyer's hæmalum and eosin and mounted in the usual way.

#### METHOD OF RECONSTRUCTION.

For the purpose of reconstruction a drawing was made on paper of every third section at a magnification of 25 diameters by means of an Edinger projection apparatus. Each sheet of paper with its drawing was then incorporated in a wax plate 2.2 mm. in thickness. The calculation for

the above is as follows:  $30 \times 25 \times 3 = 2250u$ . The hollow spaces on the drawing were next cut out with a sharp knife on glass. The plates were superimposed in their proper order and stuck together by running a hot iron round the edges. The model was divided into several pieces, suitably painted, and finally mounted so that it could be taken apart.

#### DESCRIPTION OF MODEL.

The model has been constructed so that the outer wall of the tympanum with malleus, incus, and chorda tympani can be removed in one piece in order to expose the inner wall. The part containing the labyrinth is divided into a series of nine segments, which can be separated from each other, so as to expose the labyrinthine structures. For convenience of recognition, the mucous membrane has been coloured pink, the ossicles white, the cut surfaces of lamellar bone light grey, the dense cartilage bone of the labyrinth capsule dark grey, nerves and endolymph spaces yellow, perilymph spaces blue, the carotid canal scarlet, the tensor tympani and stapedius muscles brown, and the jugular fossa dark blue. The cartilaginous part of the Eustachian tube at the one end, and the posterior part of the mastoid antrum at the other end, with its adjacent air-cells, are not included in the model. Owing to technical difficulties in mounting the model, it does not lie in its correct anatomical position, but is tilted backwards and inwards.

The study of this specimen has brought out several interesting anatomical facts. The convolvulus-like structure of the tympanic membrane is well shown, and is illustrated in fig. 7. The umbo of the malleus extends very low down on the tympanic membrane—beyond the most retracted point (fig. 11). The bony portion of the Eustachian tube lies immediately under the floor of the middle cranial fossa in its anterior part. The lumen is, moreover, not circular in section, but oblong (figs. 1 and 13). Its very close relation to the carotid canal is also well seen in figs. 1 and 16. The tensor tympani has a curved course: anteriorly it lies to the outer side of the tube (fig. 1), then above it (fig. 2), then on the inner wall of the tubal part of the tympanic cavity (fig. 4), and finally the tendon curves outwards across the tympanic cavity to reach the internal surface of the handle of the malleus. The high position of the opening of the tube into the cavity is worthy of note (figs. 15 and 16).

The floor of the tympanic cavity is formed by a thin convex plate of bone covering the jugular bulb. In places this plate of bone is dehiscant, there being only mucous membrane and fibrous tissue between the tympanum and jugular bulb (fig. 7). The roof of the cavity is also dehiscant

in places (fig. 10). There is a well-developed sinus tympani, which extends backwards in close relation to the ampullary end of the posterior semicircular canal (figs. 9 and 10). It passes between the posterior canal and the descending part of the facial nerve and reaches the posterior surface of the model (fig. 14). Some fairly large veins, draining the walls of the sinus tympani, pass directly into the jugular bulb (fig. 22). A great number of small air-cells in this case almost surrounded the semicircular canals, and also extended into the posterior wall of the deeper part of the external auditory meatus (fig. 10). The facial nerve, in its descending part, is completely surrounded by cells of varying size (figs. 10 and 14). Air-cells also extend forwards below and external to the Eustachian tube, and are separated by only a very thin plate of bone from the carotid artery (figs. 2, 3, and 15).

In this specimen the arrangement of the folds of mucous membrane round the ossicles was comparatively simple. The attic and the rest of the tympanic cavity communicate freely with each other. There were no folds binding the stapes to the neighbouring structures. It should be noted also that the opening of Prussak's space was situated anteriorly.

On the posterior surface of the bone the subarcuate fossa was very poorly marked (fig. 12). In it, however, was a leash of vessels, which could be traced through the bone from the mucous membrane of the inner wall of the antrum. These vessels pass through the loop formed by the superior canal (fig. 21). This route may explain the occurrence of meningitis following on acute otitis media in a case in which the labyrinth remains healthy.

It should be noted also that the eminence on the superior surface of the petrous bone does not correspond with the position of the superior semicircular canal; the latter lies distinctly anterior to the eminentia arcuata. The perilymphatic or cochlear aqueduct in this case does not open on the posterior surface of the petrous bone, but on the inferior surface, where it is in close relation to the glosso-pharyngeal nerve (fig. 2).

The bone immediately surrounding the labyrinth is quite distinct in structure from the rest of the petrous bone (figs. 17 and 19), being much denser and showing interglobular spaces, which contain cartilage cells. This dense bone is developed from the fetal cartilage capsule, which encloses the vesicle. The modiolus of the cochlea, on the other hand, is formed of spongy membrane bone. The facial canal passes through the upper part of this capsule to reach the inner wall of the tympanic cavity (fig. 18). The bony walls of the facial canal are composed of thin lamellar bone, which is deliquescent in parts (fig. 9), and is not part of the labyrinth capsule.



The two crura of the stapes are of almost equal length, but the anterior end of the foot plate is much longer than the posterior end.

The carotid canal lies in very close relationship to the bony capsule of the cochlea (fig. 2).

The saccule is decidedly smaller than the utricle, and the neuro-epithelium of the saccule lies at right angles to that of the utricle. The ductus reuniens is still present, and can be traced from the inferior pointed extremity of the saccule along the lamina spiralis ossea of the basal cochlear coil to open into the beginning of the cochlear canal within the vestibule (figs. 23 to 29). A well-marked crista quarta is present at the point where the lower end of the utricle receives the ampullary opening of the posterior semicircular canal (fig. 30). The horizontal canal is much shorter than the two vertical canals and has a rather wider lumen. It should also be noted that the external or horizontal canal is not horizontal, as the smooth or inner end of the canal lies considerably lower than the outer or ampullary end.

The wide distribution of the air-cells in this specimen shows that it is not advisable in every case of acute mastoiditis to attempt to open up all suppurating air-cells. In the present instance such an attempt would have necessitated a labyrinth operation. In some specimens the cochlea itself may be almost surrounded by air-cells connected with the tubal part of the tympanic cavity.

In conclusion, we wish to state that this piece of work was carried out partly in the laboratory of the Royal College of Physicians, Edinburgh, and partly in the Anatomical Department of the University of Edinburgh: we wish to acknowledge our indebtedness to Professor Robinson for the use of his reconstruction apparatus. The expenses were defrayed by a grant from the Carnegie Trust.

#### EXPLANATION OF FIGURES.

Fig. 1. Coronal section, No. 21.

- 1, Tensor tympani. 2, Eustachian tube. 3, Floor of middle cranial fossa. 4, Eighth nerve in the internal meatus. 5, Posterior surface of petrous bone. 6, Glossopharyngeal nerve and opening of aqueduct of cochlea. 7, Marrow spaces. 8, Carotid canal.

Fig. 2. Coronal section, No. 97.

- 1, Tensor tympani. 2, Apical coil of cochlea. 3, Middle coil. 4, Cochlear nerve in internal meatus. 5, Cranial end of aqueduct of cochlea (perilymph). 6, Basal coil of cochlea. 7, Carotid canal. 8, Tubal portion of tympanic cavity.



Fig. 3. Coronal section, No. 127.

- 1, Tensor tympani. 2, Helicotrema. 3, Canal for great superficial petrosal nerve.
- 4, Modiolus. 5, Facial nerve. 6, Cochlear aqueduct. 7, Edge of cochlear cartilage bone capsule. 8, Carotid canal. 9, Tubal cells. 10, Tubal part of tympanic cavity.

Fig. 4. Coronal section, No. 175.

- 1, Tensor tympani. 2, Facial nerve passing above cochlea. 3, Vestibular ganglion.
- 4, Cochlear aqueduct. 5, Jugular bulb. 6, Air-cells in floor of tympanic cavity. 7, Tympanic cavity.

Fig. 5. Coronal section, No. 211.

- 1, Facial nerve. 2, Internal meatus with vestibular nerve. 3, Vein accompanying perilymphatic aqueduct. 4, Jugular bulb. 5, Air-cell in floor of tympanic cavity. 6, Scala tympani of basal coil. 7, Tympanic cavity. 8, Tensor tympani.

Fig. 6. Coronal section, No. 244.

- 1, Anterior part of epitympanic cavity. 2, Facial nerve. 3, Anterior part of utricle.
- 4, Cochlear opening of perilymphatic aqueduct. 5, Jugular bulb. 6, Tympanic air-cells. 7, Tympanic membrane. 8, External meatus. 9, Tympanic cavity. 10, Sacculus. 11, Tensor tympani.

Fig. 7. Coronal section, No. 295.

- 1, Tensor tympani. 2, Facial nerve. 3, Utricle. 4, Ampulla of superior canal with crista. 5, Opening of crus commune. 6, Superior canal. 7, Sinus of posterior canal with crista quarta. 8, Niche of round window. 9, Jugular bulb. 10, Promontory. 11, External meatus. 12, Handle of malleus attached to drum-head. 13 and 14, Head and footplate of stapes.

Fig. 8. Coronal section, No. 352.

- 1, External attic. 2, Head of malleus. 3, Facial nerve. 4, Two ends of external canal. 5, Superior canal. 6, Remains of fossa subarcuata in labyrinth nucleus. 7, Ductus endolymphaticus. 8, Two ends of posterior canal. 9, Jugular bulb. 10, Hypotympanum. 11, External meatus. 12, Tympanic membrane. 13, Stapes. 14, Prussak's space.

Fig. 9. Coronal section, No. 385.

- 1, Head of malleus. 2, Body of incus. 3, External canal. 4, Air-cells. 5, Part of endolymphatic sac. 6, Two ends of posterior canal.

Fig. 10. Coronal section, No. 523.

- 1, Roof of mastoid antrum. 2, Cavity of antrum. 3, Posterior canal. 4, Air-cells. 5, Sacculus endolymphaticus. 6, Air-cells. 7, Sinus tympani. 8, Facial nerve. 9, Chorda tympani. 10, External meatus. 11, Border air-cells overhanging external meatus.

Fig. 11. Lateral aspect of model.

- 1, Short process of malleus. 2, Umbo. 3, Anterior wall of external meatus. 4, Membrana tympani. 5, Posterior wall of external meatus. 6, Air-cells.

Fig. 12. Postero-medial surface of model.

- 7, Subarcuate fossa. 8, Opening for sacculus endolymphaticus. 9, Seventh and eighth nerves. 10, Internal meatus.

Fig. 13. Anterior surface of model.

- 9, Eighth nerve. 10, Internal meatus. 11, Eustachian tube. 12, Capsule of cochlea. 13, Marrow spaces. 14, Facial nerve. 15, Carotid canal. 16, Tensor tympani.

Fig. 14. Posterior surface of model.

- 6, Aditus. 8, Opening for saccus endolymphaticus. 12, Capsule of posterior canal. 14, Facial nerve. 17, Border air-cells. 18, Chorda tympani. 19, Sinus tympani. 20, Air-cells.

Fig. 15. Outer wall of tympanic cavity.

- 4, Tympanic membrane. 11, Eustachian tube. 14, Facial nerve. 15, Carotid canal. 16, Tensor tympani. 18, Chorda tympani. 20, Air-cells. 21, Handle of malleus. 22, Attic. 23, Head of malleus. 24, Body of incus. 25, Posterior ligament of incus. 26, Jugular bulb. 27, Floor of tympanum.

Fig. 16. Inner wall of tympanic cavity.

- 6, Air-cells of antrum. 11, Eustachian tube. 14, Facial nerve. 15, Carotid canal. 16, Tensor tympani. 19, Sinus tympani. 27, Floor of tympanum. 28, Eminence of external canal. 29, Promontory. 30, Niche of round window. 31, Stapes. 32, Facial canal.

Fig. 17. Posterior surface of segment B.

- 2, Helicotrema. 4, Modiolus. 9, Eighth nerve. 11, Eustachian tube. 13, Marrow spaces. 14, Facial nerve. 33, Scala tympani of basal coil. 35, Aqueduct of cochlea. 36, Scala vestibuli of basal coil.

Fig. 18. Posterior surface of segment C.

- 10, Fundus of internal meatus. 12, Capsule of labyrinth. 13, Marrow spaces. 14, Facial nerve. 16, Tensor tympani. 33, Scala tympani of basal coil. 34, Scala vestibuli of middle coil. 35, Aqueduct of cochlea. 39, Vein accompanying aqueduct of cochlea. 40, Vestibular ganglion.

Fig. 19. Posterior surface of segment D.

- 12, Labyrinth capsule. 13, Marrow spaces. 14, Facial nerve. 20, Air-cells. 26, Jugular fossa. 27, Floor of tympanum. 44, Footplate of stapes. 45, Scala vestibuli opening into vestibule. 46, Promontory. 47, Opening of aqueduct of cochlea. 48, Branch of vestibular nerve. 49, Vestibule. 50, Branch of vestibular nerve.

Fig. 20. Anterior surface of segment E.

- 13, Marrow spaces. 14, Facial nerve. 20, Air-cells. 26, Jugular fossa. 31, Stapes. 46, Promontory. 47, Membrane of round window. 51, Utricle. 52, Sacculle. 53, Ductus reuniens.

Fig. 21. Posterior surface of E.

- 12, Labyrinth capsule. 13, Marrow spaces. 26, Jugular fossa. 31, Stapes. 54, Membranous superior semicircular canal. 55, Ampulla of external canal. 56, Ampulla of posterior canal. 57, Ductus endolymphaticus. 58, Posterior end of external canal. 59, Crus commune. 60, Superior canal. 61, Sub-arcuate veins.

Fig. 22. Posterior surface of G.

- 6, Air-cells. 8, Opening for saccus endolymphaticus. 14, Facial nerve. 19, Sinus tympani. 62, Posterior canal. 63, Stapedius. 65, External canal. 67, Veins from sinus tympani to jugular bulb.

Figs. 23-29. Camera lucida drawings showing the ductus reuniens. Slides 243 and 252 are drawn at a low magnification. Slides 267, 287, 294, 302, and 315 are drawn to scale at a higher magnification.

- 1, Utricle. 2, Sacculc. 3, Aqueduct of cochlea. 4, Scala tympani. 5, Scala media. 6, Communication between scala vestibuli and perilymphatic space of vestibule. 7, Ductus reuniens. 8, Lamina spiralis ossea. 9, Membrane of round window. 10, Niche of round window.

Fig. 30. Slide 317.

- 1, Crista of superior canal. 2, Junction of ampulla of superior canal with utricle. 3, Perilymph space of vestibule. 4, Nucleus of labyrinth. 5, Non-ampullated end of superior membranous canal opening into utricle. 6, Lower part of utricle. 7, Crista quarta at junction of ampulla of posterior canal with utricle. 8, Neuro-epithelium (crista) of posterior canal. 9, Ductus reuniens (see fig. 29). 10, Beginning of scala tympani of cochlea. 11, Niche of round window. 12, Promontory. 13, Head and footplate of stapes. 14, Facial nerve.

A full account of the comparative anatomy of the crista quarta by Benjamin will be found in the *Zeitschrift für Ohrenheilkunde*, 1913, Band lxxviii. p. 101.



FIG. 1.—Coronal section, No. 21.

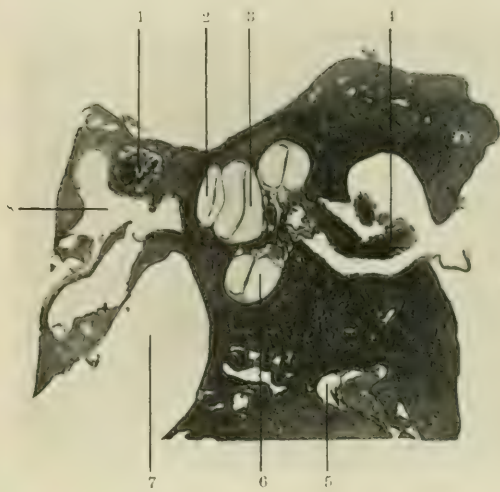


FIG. 2.—Coronal section, No. 97.

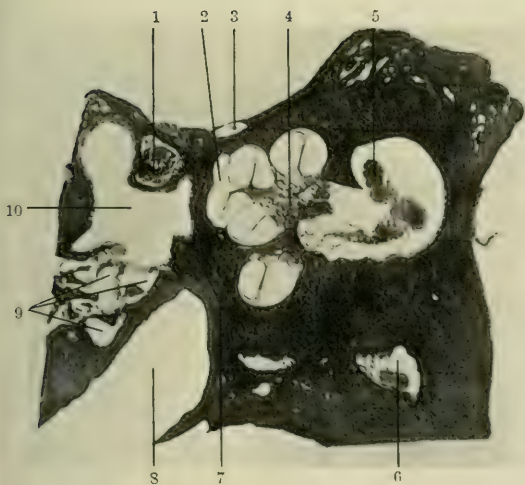


FIG. 3.—Coronal section, No. 127.

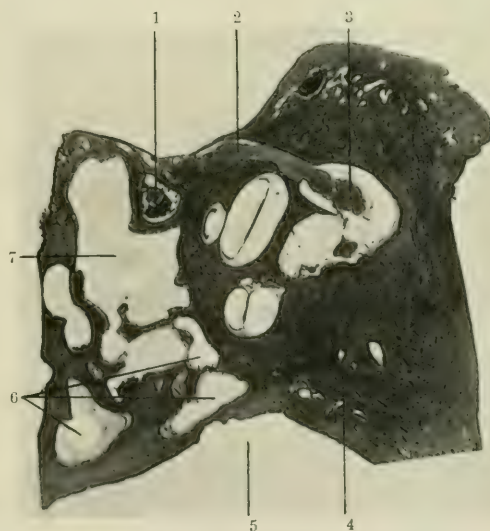


FIG. 4.—Coronal section, No. 175.



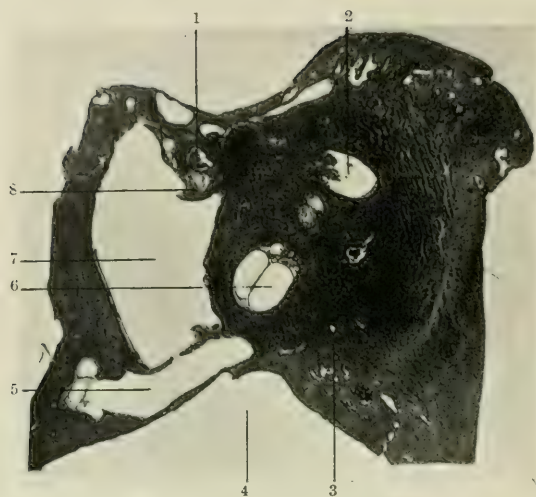


FIG. 5.—Coronal section, No. 211.

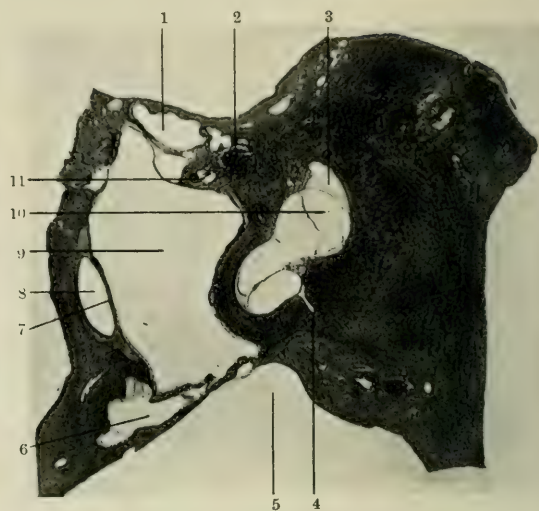


FIG. 6.—Coronal section, No. 244.

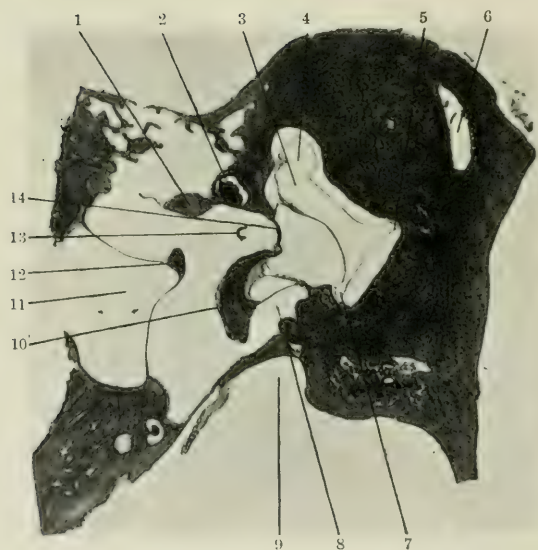


FIG. 7.—Coronal section, No. 295.



FIG. 8.—Coronal section, No. 352.

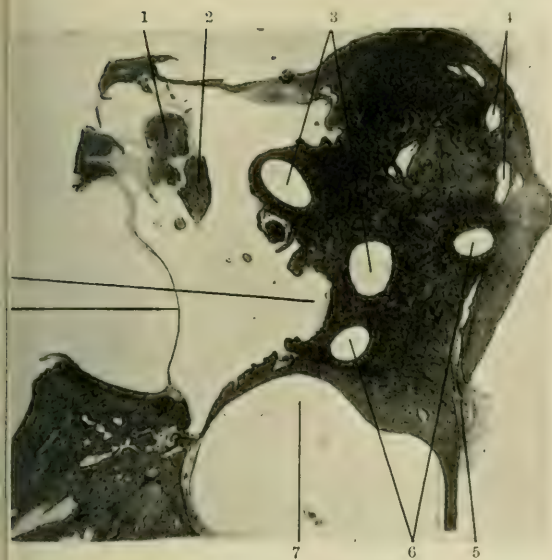


FIG. 9.—Coronal section, No. 385.



FIG. 10.—Coronal section, No. 523.



FIG. 11.—Lateral aspect of model.



FIG. 12.—Postero-medial surface of model.



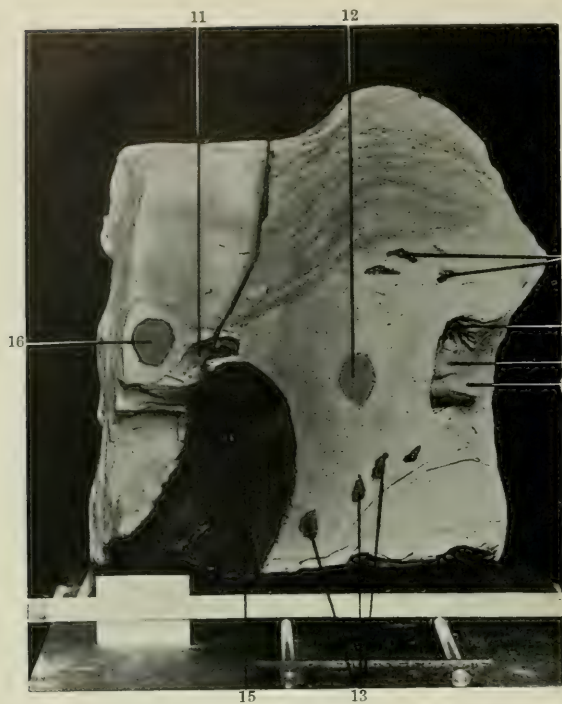


FIG. 13.—Anterior surface of model.

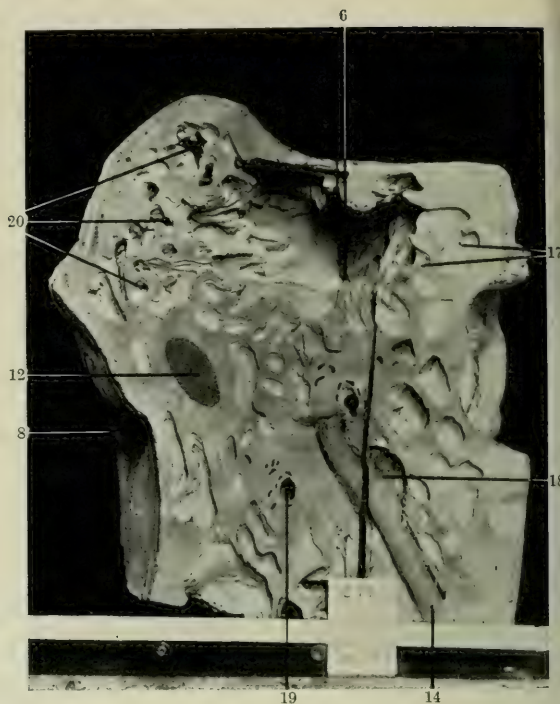


FIG. 14.—Posterior surface of model.

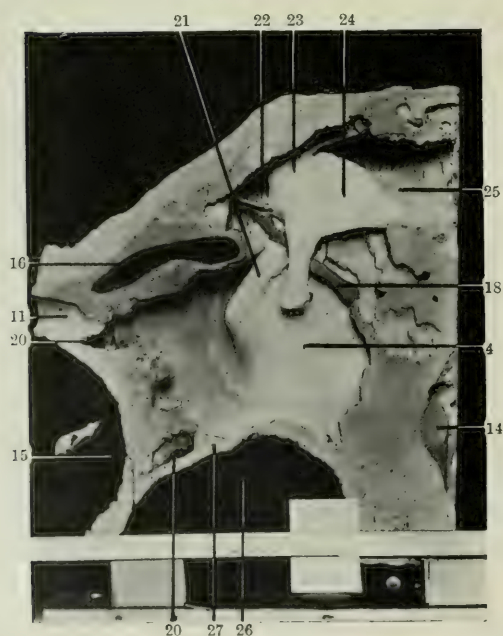


FIG. 15.—Outer wall of tympanic cavity.

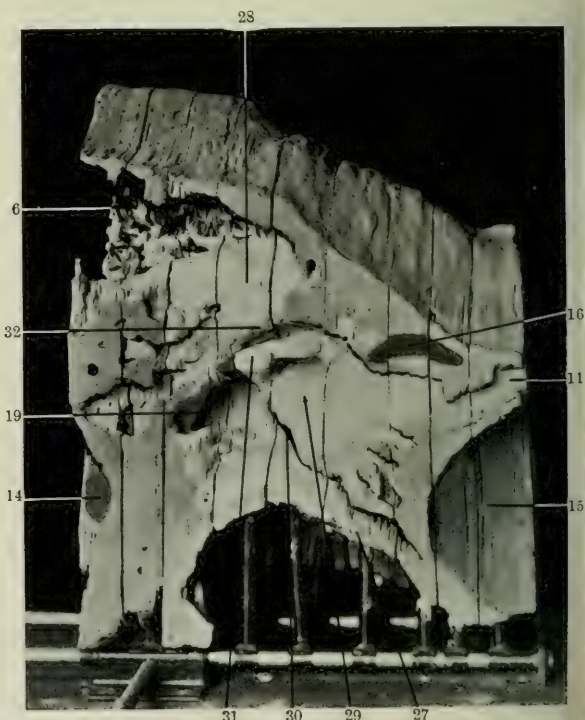


FIG. 16.—Inner wall of tympanic cavity.

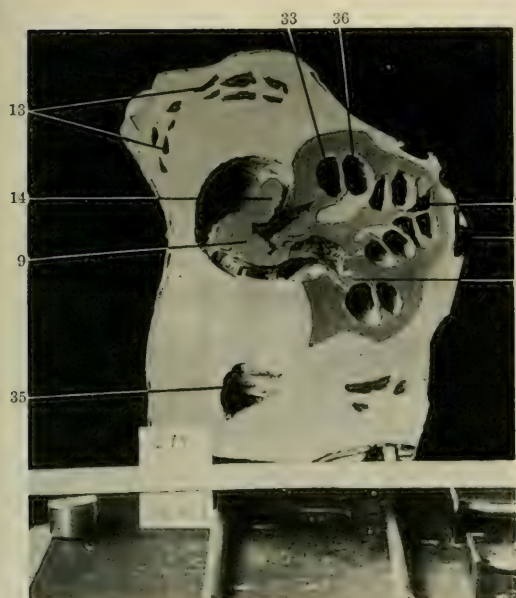


FIG. 17.—Posterior surface of segment B.

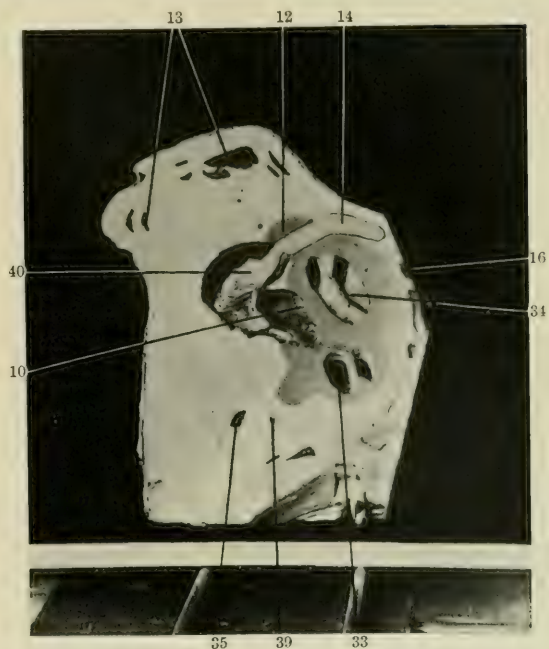


FIG. 18.—Posterior surface of segment C.

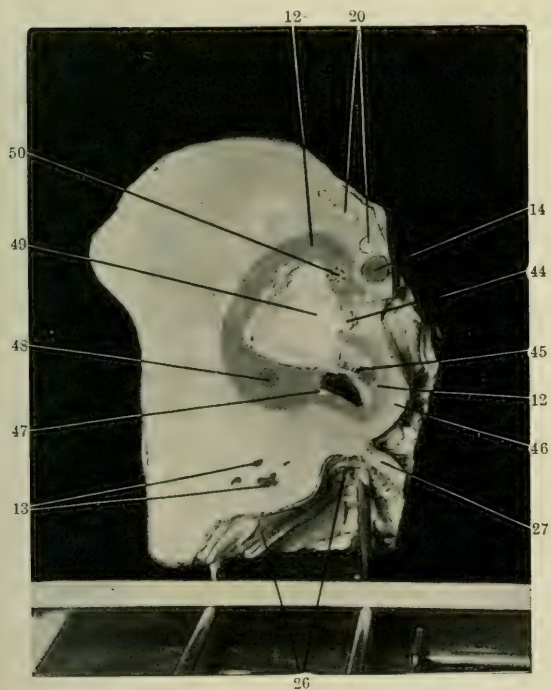


FIG. 19.—Posterior surface of segment D.

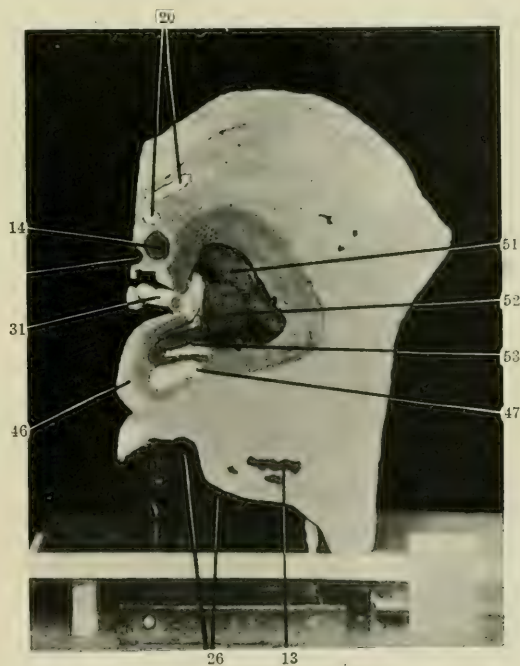


FIG. 20.—Anterior surface of segment E.



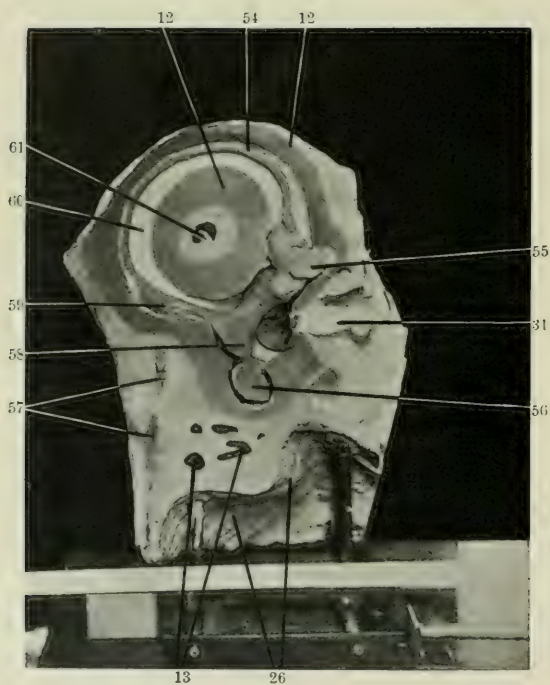


FIG. 21.—Posterior surface of E.

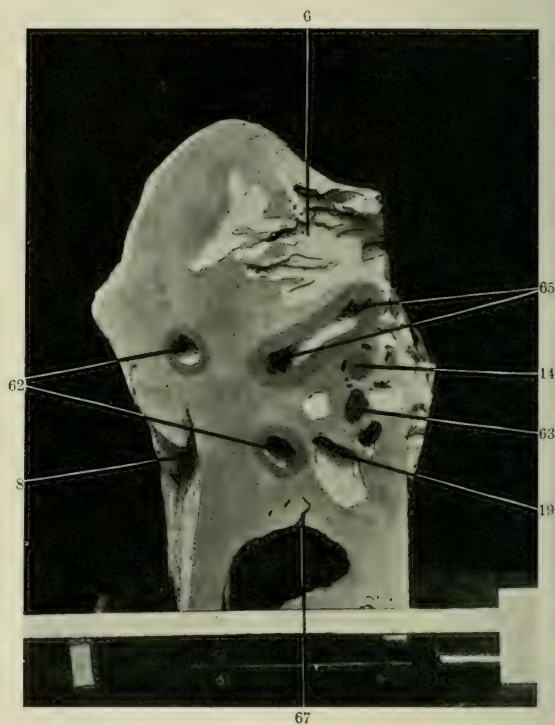


FIG. 22.—Posterior surface of G.

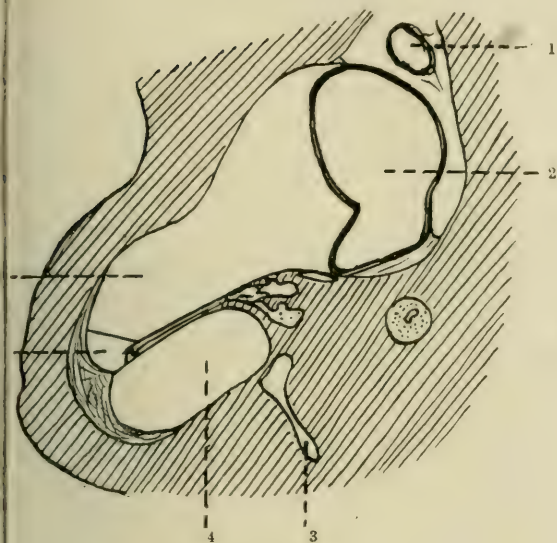


FIG. 23.—Slide 243.

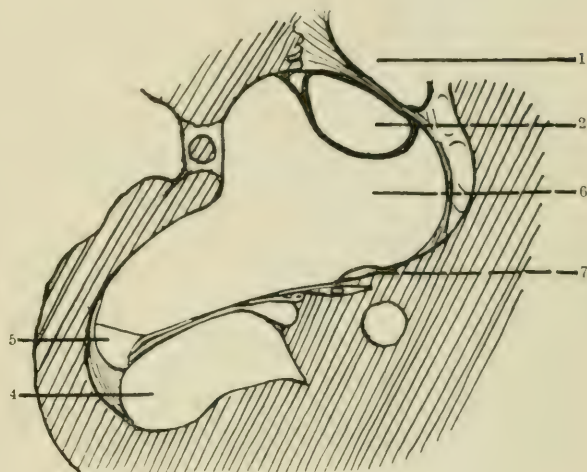


FIG. 24.—Slide 252.

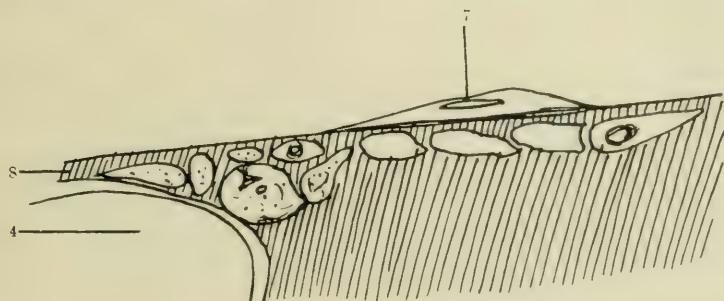


FIG. 25.—Slide 267.

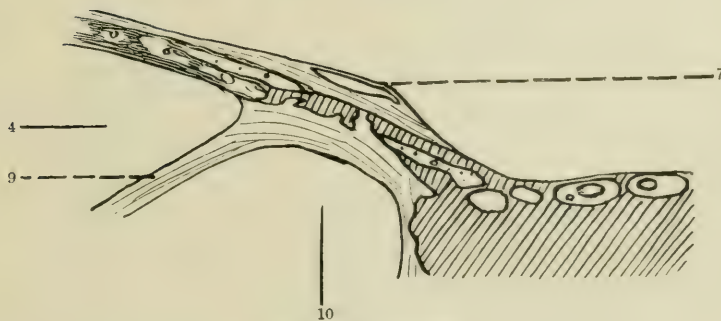


FIG. 26.—Slide 287.

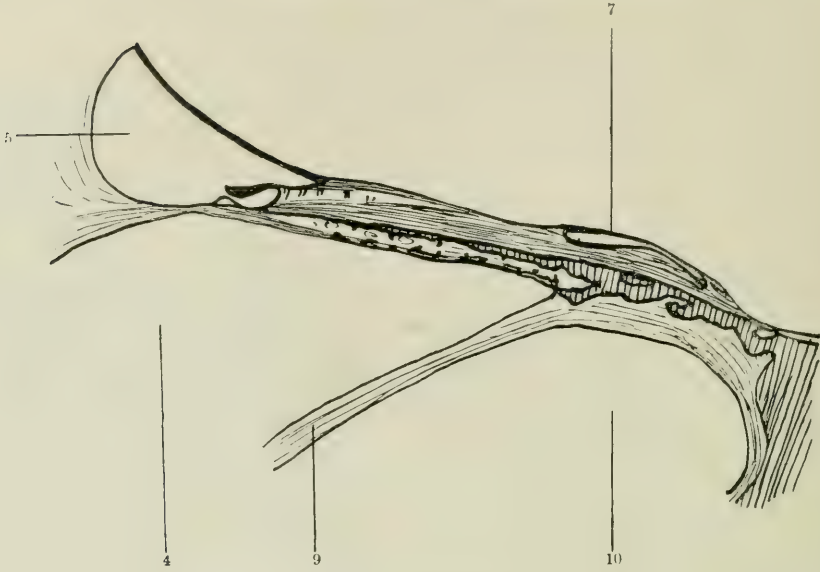


FIG. 27.—Slide 294.

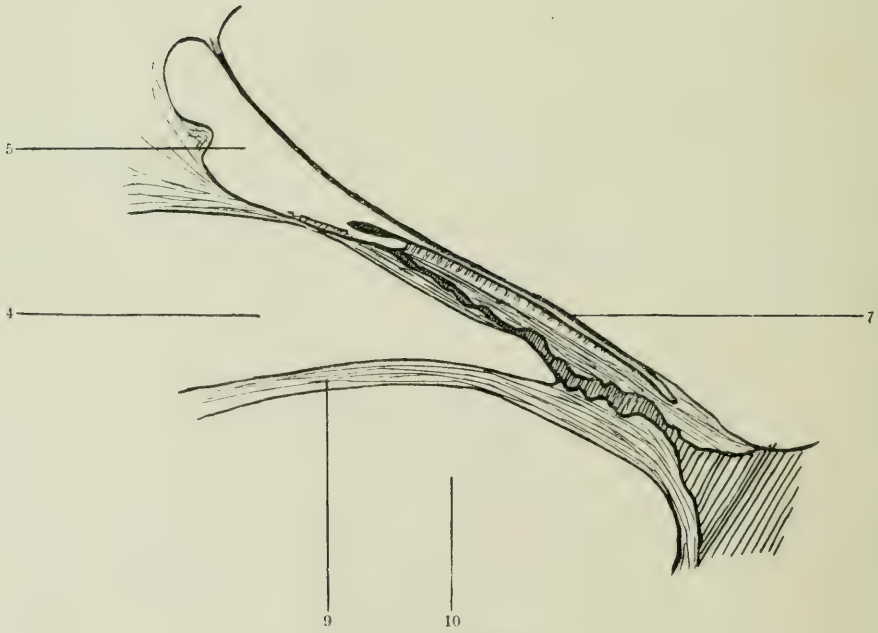


FIG. 28.—Slide 302.

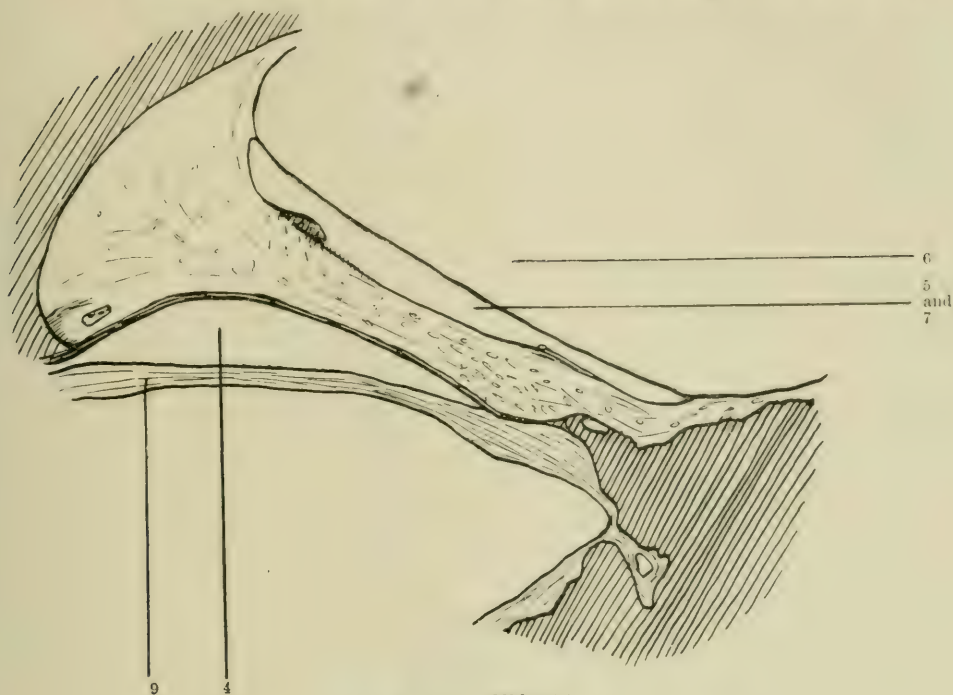


FIG. 29.—Slide 315.



FIG. 30.—Slide 317.



## A CASE OF ABNORMAL DISPOSITION OF THE PERITONEUM.

By S. V. TELFER, M.B., *Demonstrator of Anatomy, University of Durham.*

THE following case from the dissecting-room of the University of Durham, College of Medicine, Newcastle-upon-Tyne, presents some points of embryological interest.

The subject was a male, æt. 54. The previous history is unknown, but the cause of death had no relation to the intestinal condition to be described.

When the abdomen was opened, the disposition of the peritoneum and the small intestine was seen to be abnormal. A large open-mouthed sac, formed by a peritoneal reflection, and containing a part of the small intestine, occupied the right side of the abdominal cavity. It extended medialwards to the right side of the vertebral column, upwards to the transverse colon, and lateralwards to the ascending colon. The anterior wall of the sac was formed by a double layer of peritoneum. The peritoneum of the posterior abdominal wall limited it behind. It was open below, and from the opening the jejunum and its mesentery issued. The anterior free margin of the opening was crescentic in shape, and was formed by that part of the root of the mesentery which normally fixes the ileum to the posterior abdominal wall (fig. 1). The sac contained about four feet of the jejunum with its mesentery. The contents were tightly packed, but there was no evidence of constriction in any part of the bowel.

The duodenum lay wholly on the right side of the vertebral column. From the pylorus it passed for a distance of one inch horizontally to the right, then vertically downwards to the level of the lower border of the second lumbar vertebra. From this point it doubled backwards on itself, and ascended almost to the level of the first part (fig. 2). The adjacent walls of the ascending and descending limbs were adherent. The bowel finally passed downwards and slightly medialwards, reaching the side of the second lumbar vertebra, where it pierced the upper wall of the abnormal peritoneal sac and became continuous with the jejunum.

The upper four feet of the latter portion of the bowel were coiled up within the sac. From the point where it emerged, the rest of the small intestine lying in the general peritoneal cavity could be easily followed to the ileo-colic junction.



FIG. 1.

The line of attachment of the mesentery was irregular. From the right side of the body of the second lumbar vertebra, in the upper limit of the sac, it could be followed down to the fourth lumbar vertebra where it emerged from the sac with the jejunum. This part of the mesentery was very short, though it contained much fat. The rest of the mesentery crossed the middle line to the left side, and passed up to the left side of the third lumbar vertebra. It finally arched to the right, forming the

anterior free margin of the mouth of the sac. It terminated at the ileo-colic junction.

The first three or four branches of the superior mesenteric artery, springing from the left convex side of the vessel, curved behind the latter, before being directed to the right, where they entered the attachment of the jejunal mesentery within the sac. The ileo-colic artery passed to the caecum in the crescentic margin of the mouth of the sac. The situation of the right and middle colic vessels was especially noteworthy; these ran to the large intestine, between the peritoneal layers, forming the anterior wall of the sac. No branches of the superior mesenteric artery were found behind the peritoneum, which formed the posterior wall.

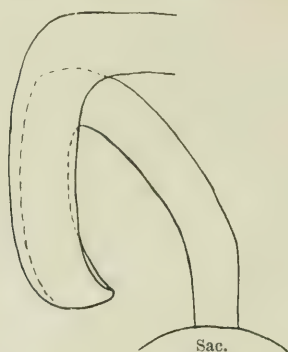


FIG. 2.—Form of duodenum (semi-diagrammatic).

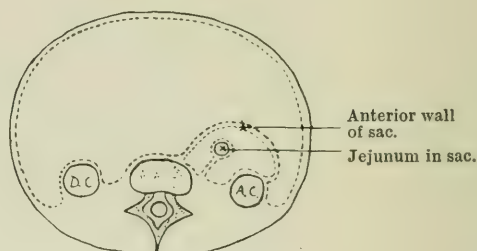


FIG. 3.—Transverse section across sac (diagrammatic).

The explanation of this condition is to be found in an abnormal process of development. About the sixth week of foetal life, when the gut rotates on the long axis of the superior mesenteric artery, the ascending colon is carried to the right across the front of the small intestine. The mesentery accompanies the gut, and the post-arterial part which lies between the vessel and the large bowel normally disappears by fusing with the peritoneum of the posterior abdominal wall. In this case it has persisted and formed the anterior wall of the abnormal sac (fig. 3). This view is supported by the situation of the right and middle colic branches of the superior mesenteric artery, which run to the large bowel, between the folds forming the anterior wall of the sac.

It is impossible to state definitely whether the condition described above is due to the arrest of rotation of the upper portion of the gut by the adhesion of the walls of the duodenum, or whether such adhesion is secondary to failure of rotation from some other cause. The peculiar

distribution of the upper intestinal vessels, however, suggests that the adhesion of the walls is the primary factor, and this has interfered with the normal translation of the proximal portion of the gut to the left. The lower part of the small bowel has undergone the usual excursion.

While the persistence of the post-arterial part of the primitive mesentery is not uncommon, the very complete state in which it was found in this case, and the curious form and position of the duodenum, seem to be worthy of record.



A SPECIMEN SHOWING COMPLETE REMAINS OF THE LEFT  
SUPERIOR VENA CAVA; WITH A DESCRIPTION OF A  
VENULE, WHICH REPRESENTS THE "LOST" EXTRA-  
PERICARDIAC PORTION OF THE LEFT DUCT OF CUVIER.  
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Hospital Medical School.*

THE writer's attention was attracted to the specimen which forms the subject of this communication by the discovery of a small yet prominent venous channel, passing from the pericardium to the left superior intercostal vein, and apparently acting as a drainage vessel for this membrane. On measurement it was found to be 42 mm. long, and 1 mm. in average breadth in the collapsed condition. It entered the left superior intercostal vein 24 mm. from the point of union of the latter with the left innominate, and exactly at the junction of what I would term its horizontal and vertical portions. The left superior intercostal vein thus makes a decided bend upwards at this point (figs. 1 and 4). It is important, therefore, to recognise at this stage that this vertical part (24 mm. long in the specimen as stated above) is the only portion of the left superior intercostal vein which will be subsequently proved to belong to the left superior vena cava, and it is, moreover, the portion derived from the left anterior cardinal vein. The horizontal part, on the other hand, corresponds to the arch of the vena azygos major (see fig. 2), and is, like it, a derivative of the posterior cardinal vein. This sudden bend of the left superior intercostal vein is thus of embryological and morphological importance.

What directed attention to the specimen first of all was the fact that the peripheral end of the venule was attached to the pericardium exactly at the origin of the left pulmonary artery, and it suddenly struck the writer that this minute and apparently insignificant vessel might represent the "lost" extra-pericardiac portion of the left duct of Cuvier, which from its very position would of course connect the fibrous cord contained in the vestigial fold of Marshall to the left superior intercostal vein, and ought therefore to be attached to the fibrous pericardium at the root of origin of the left pulmonary artery. On further examination of the specimen this early surmise was found to be correct (fig. 1).

The course of the venule was upwards and to the left over the root of the left pulmonary artery, in front of the ligamentum arteriosum (which was particularly prominent in the specimen) and upwards over the arch of the aorta, to enter the left superior intercostal vein just after the latter vessel had crossed in front of the origin of the left subclavian artery in order to gain the left innominate. Whilst crossing the arch of the aorta the venule lay 5 mm. to the right of the left vagus nerve and in front of the small cervical cardiac branches of the left vagus and sympathetic. It

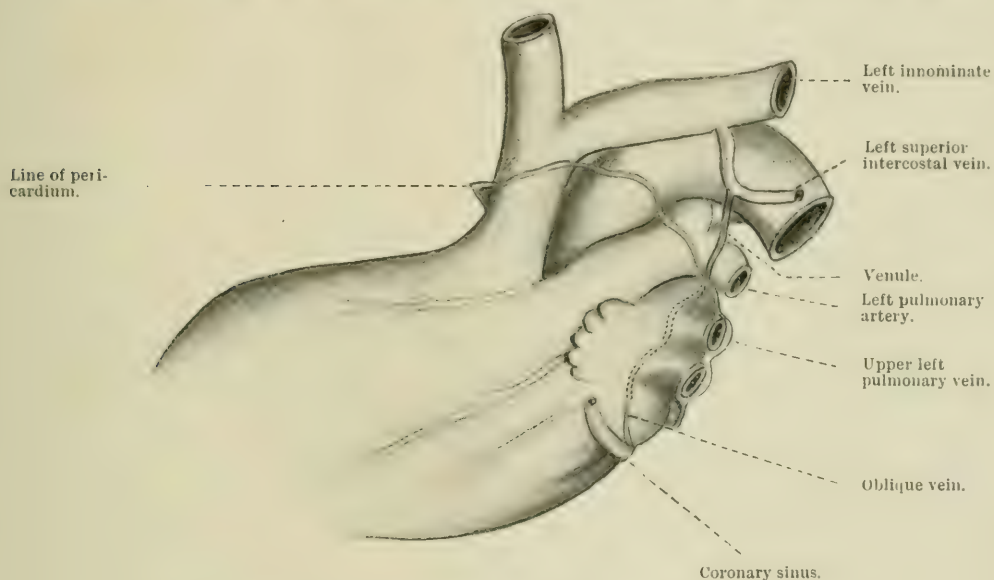


FIG. 1.—A sketch of the specimen showing complete remains of the left superior vena cava, including the venule.

was of course overlapped throughout its whole extent by the left lung and pleura. The left phrenic nerve had unfortunately been dislodged before the importance of the specimen was recognised, but I have been able to study the venule in several undisturbed thoraces, the result being to disclose a remarkably constant and characteristic relationship of this nerve to the vessel. The best method of displaying the venule in an undissected thorax is as follows:—After removal of the anterior chest wall, open the left pleural sac, pull the anterior edge of the left lung outwards, and define the position of the left phrenic nerve high up, as it lies under cover of the mediastinal pleura. Incise the mediastinal pleura along the line of the nerve, and pull the latter with its companion vessels gently to the

left. Now define the left superior intercostal vein as it crosses the aorta, and also locate the root of the left pulmonary artery just as it emerges from the fibrous pericardium. A little gentle dissection in the loose tissue occupying the interval between these points will expose the vessel in question. It can be made out without material difficulty in most cases, particularly if the veins of the thorax have been for some reason or other markedly engorged with blood immediately before death. Under these favourable conditions it will be observed that the main duty of the venule is to act as a drainage channel for the blood from the pericardium; but, in addition to this, it receives on its way upwards one or two minute tributaries from the tissues of the mediastinum. If the minute radicles of origin from the pericardium be closely examined, one of these will be found to be in direct continuity with the fibrous cord contained within the vestigial fold of Marshall; whilst the further connexion of the latter with the oblique vein is readily demonstrable.

One is now able to appreciate fully the relation of the vestigial fold to the left superior vena cava, and to compare it with the right superior vena cava. In the intrapericardial part of its course, the right superior vena cava is situated immediately in front of the right pulmonary artery and upper right pulmonary vein, and it is covered in front and at the sides by the serous pericardium. Now imagine for a moment this vessel becoming obliterated. The result would be a "vestigial fold" of serous pericardium passing from the right pulmonary artery to the upper right pulmonary vein, and containing within its anterior free border a fibrous cord representing the right superior vena cava. In other words, the vestigial fold of Marshall would be transferred to the right side, similar in every particular to the condition with which we are familiar on the left.

The writer consulted the catalogue of the Royal College of Surgeons Museum relating to the abnormalities of the venous system, and found that specimen 569.1 was a splendid example of a left superior vena cava persisting in an adult (fig. 2). In this specimen the vessel (which was actually larger than the right superior vena cava) crossed in front of the aortic arch, and passed vertically downwards *anterior to the roots of the left pulmonary artery and upper left pulmonary vein*. This relation, of course, determines the position of the vestigial fold of Marshall. It then curved backwards below the lower left pulmonary vein to become continuous with a much dilated coronary sinus. The vessel was joined at right angles on its posterior aspect by the horizontal portion of the left superior intercostal vein. The latter thus clearly corresponds to the vena azygos major (see fig. 2). It is obvious, then, that the vertical part of the left

superior intercostal vein is normally derived from the upper end of the left superior vena cava, so that one at once understands the significance of the familiar right-angled bend of the left superior intercostal. In specimen 569.1 the left innominate vein was reduced to a comparatively small cross channel which received from above a tributary presumably representing the common stem of junction of the inferior thyroid veins. The account of the specimen in the catalogue is as follows: "An adult human heart with a persistent left superior vena cava. The two venæ cavæ are united by a slender transverse vessel which receives the inferior thyroid vein."'

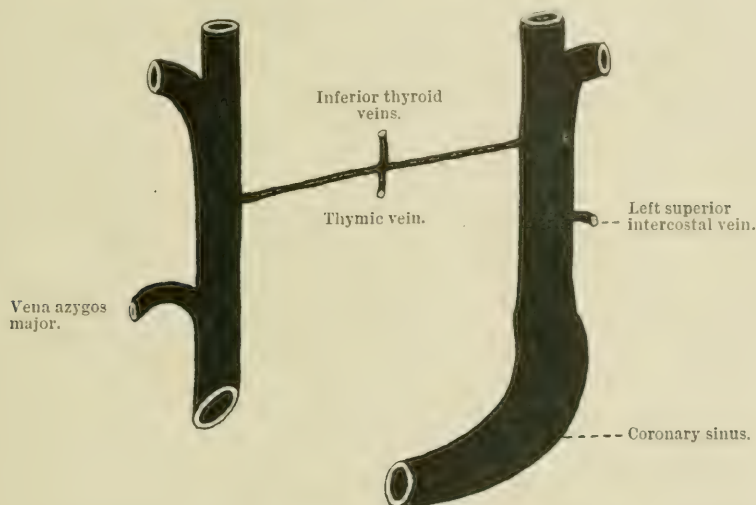


FIG. 2.—Outline sketch of the superior venæ cavæ in specimen 569.1 Royal College of Surgeons Museum. The left innominate is shown as a slender cross stem which receives the inferior thyroid and thymic veins.

A further examination of the slender left innominate vein revealed the presence of a short venous stump entering from below, directly opposite the junction of the inferior thyroid stem. This the writer regards as the thymic vein. The specimen does not show the relation of the phrenic nerves to the superior venæ cavæ.

The writer can find no description of this small pericardiac venule in text-books of anatomy. Dr R. J. Gladstone informs me that he has noticed its existence. It is usually stated that the left superior vena cava is represented in the adult by the left superior intercostal vein, the vestigial fold of Marshall, and the oblique vein. There is thus manifestly a big gap between the left superior intercostal vein and the vestigial fold, and the writer holds that the venule described above is the structure which fills



up this hiatus. If one draws a diagram of the cardinal veins and ducts of Cuvier, it will be noted that the intermediate part of the left duct becomes obliterated to form the cord in the vestigial fold. The lower segment is the oblique vein. The upper part is outside the pericardium, and must of course be connected above with the left superior intercostal vein. Professor A. Keith gives a diagram of this nature in his text-book of *Embryology*, and he, in fact, states<sup>1</sup> that "the extra-pericardiac part of the left duct of Cuvier joins the superior intercostal vein." The embryological evidence on the subject is thus very definite indeed.

Dr R. J. Gladstone very kindly placed at the writer's disposal a beautiful series of transverse sections of a 10-mm. human embryo, which showed the right phrenic nerve lying directly on the lateral aspect, and the vagus nerve on the mesial aspect of the right superior vena cava. The remarkable thing, however, was that the corresponding nerves of the left side bore an exactly similar relationship to the left superior vena cava (see fig. 3). The latter is of the same size as the right vessel in the 10-mm. human embryo, so that at this stage of development there is a symmetry, not only of the two venæ cavæ, but also of the phrenic and vagus nerves in relation to these. Another striking fact is that there is also a symmetrical arrangement of the tributaries of the venæ cavæ. For instance, the arch of the vena azygos major corresponds to the horizontal portion of the left superior intercostal vein (as fig. 2 shows), whilst each vena cava in addition receives pericardiac and mediastinal veins. Lying lateral to both phrenic nerves in this embryo was a small vascular channel. This the writer regards as the vein of the arteria comes nervi phrenici, a conclusion which is supported by the adult relations of these structures, as will be shown presently.

On comparing this with the adult, one finds an absolute persistence of the intimate relationship of the left phrenic nerve to the extrapericardiac remains of the left superior vena cava (represented by the venule and the left superior intercostal vein); for it will be found that it courses downwards directly lateral to the vertical portion of the latter vessel, crosses in *front* of the horizontal portion, and then runs on the lateral aspect of the venule throughout its whole course (see fig. 4). The left vagus nerve, on the other hand, always lies *behind* the horizontal portion of the left superior intercostal vein, and it may be further noted that the arch of the vena azygos major, to which this corresponds on the right side, always intervenes between the right phrenic and vagus nerves.

The vein of the left arteria comes nervi phrenici (the superior phrenic) would be found lying on the lateral aspect of the left phrenic nerve (fig. 4),

<sup>1</sup> Third edition, 1913, p. 285.

so that this vessel also maintains its embryonic (10-mm. embryo) relationship to the nerve (see fig. 3). This vein on being traced upwards will be found to join the horizontal portion of the left superior intercostal,

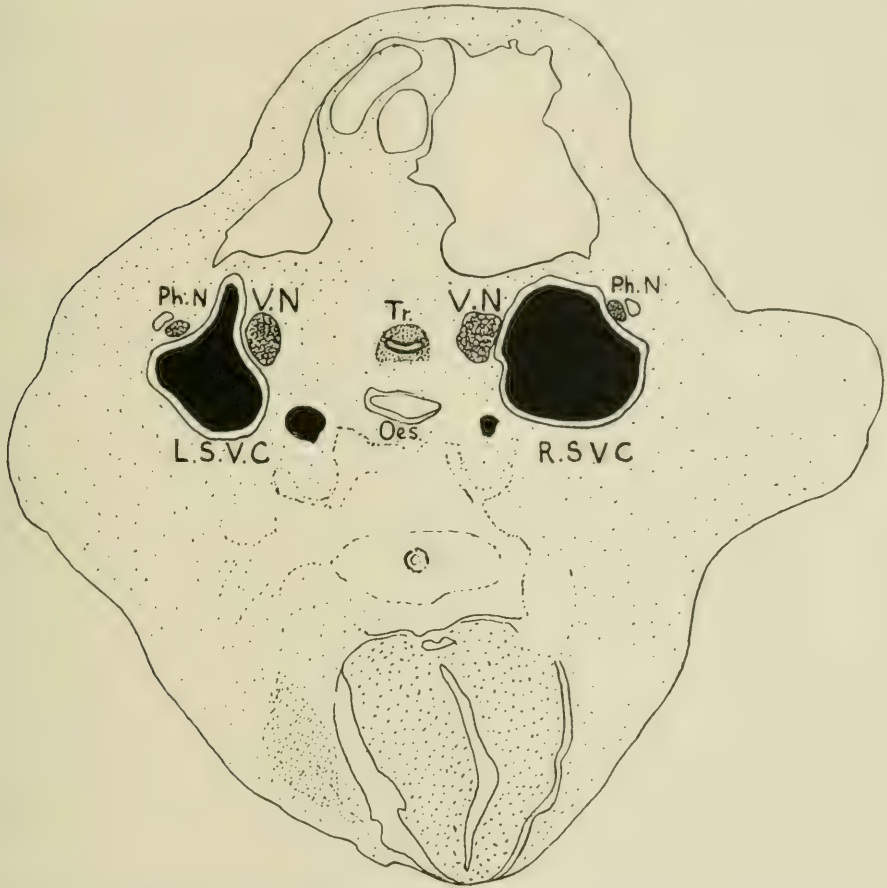


FIG. 3.—Transverse section of a 10-mm. human embryo, showing the relations of phrenic and vagus nerves to the right and left superior venæ cavae. From a specimen kindly lent by Dr R. J. Gladstone.

usually to the left of the point where it is crossed anteriorly by the left phrenic (see fig. 4). The venule, on a casual examination, might quite readily come to be regarded as a second superior phrenic vein, but a closer inspection shows that this is not so. The writer has always concluded that the superior phrenic vein ought of necessity to join the internal mammary vein; but the above termination has been very definitely shown

in all the thoraces he has examined since his attention was directed to it. It is intended to continue this investigation in order to ascertain if this is the most common mode of termination of this vein. The only text-book of anatomy the writer has had access to, which makes a definite statement regarding the way in which this vein ends, is *Gray's Anatomy*, 18th edition, 1913, p. 684, where it is stated that the left superior intercostal vein sometimes receives the "left superior phrenic vein." It is difficult to explain

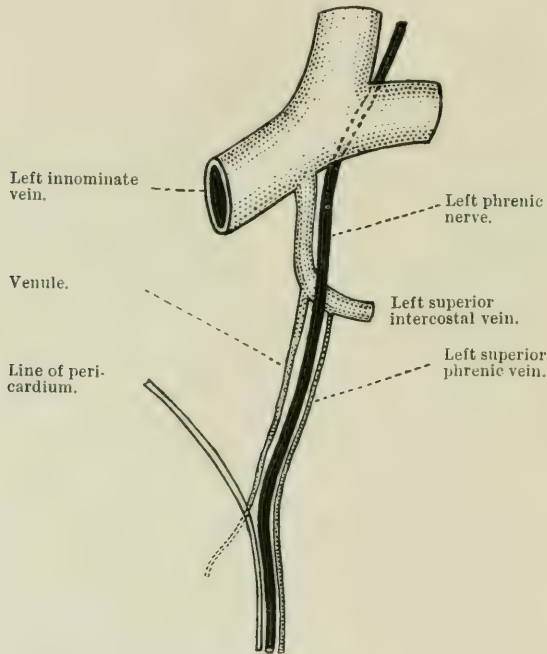


FIG. 4.—Showing the relation of the left phrenic nerve to the venule, the left superior intercostal and the left superior phrenic veins.

why veins so often exhibit this tendency to enter the first trunk they come to, instead of their own parent stem, except on the assumption that it is a result of the plexiform arrangement which is such a feature of the venous system in the embryo. In association with this idea one might note the union of the umbilical vein with the left branch of the portal, the junction of the middle sacral with the left common iliac, and above all the plexiform arrangement produced by the inferior thyroid and thymic veins which probably forms the foundation or basis of the left innominate vein. Fig. 2 is most suggestive on this question, which will be discussed more fully

in a subsequent paper dealing with the development of the left innominate vein.

In conclusion the writer wishes to express his warm thanks to Professor A. Keith for so kindly permitting the drawing of preparation 569.1 in the Royal College of Surgeons Museum, and for the keen interest he has shown in the specimen: and also to Dr R. J. Gladstone for his never-failing kindness in granting the use of his admirable series of sections of a 10-mm. human embryo.



A CASE OF DUPLICATION OF THE URETERS. By CECIL P.  
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College, London.*

DUPLICATION of the ureters is of interest not only on account of its obvious surgical importance, but also on account of the bearing it has upon the study of variation from the morphological standpoint. This condition is often accompanied by other variations of the urogenital system: namely, in the position, form, and size of the kidney and in the renal arteries and veins. From a surgical point of view the mode of termination (*i.e.* a single or double opening) of the ureters in the bladder is of considerable interest; for example, in the case of stone in one ureter, if a radiographic bougie was passed into the sound ureter, an X-ray photograph would show a shadow to the side of the bougie, and it might be concluded that the shadow was not due to a renal calculus, although such existed in the second ureter.

The subject in which the present example of this anomaly occurred was a male aged 68 years in the Anatomical Laboratory, King's College. The ureters on both sides were double and pervious. Both kidneys were enlarged, the measurement of the kidneys being:—

	Right kidney.	Left kidney.	Average.
Length . . .	15·2 cms.	10·4 cms.	11·5 cms.
Breadth . . .	6·3 „	5·7 „	5·2 „
Thickness . . .	5 „	4·5 „	3·2 „
Weight . . .	170·1 grams.	143·75 grams.	127·57 grams.

The details of the condition are as follows:—On the right side each ureter commenced as a separate pelvis, the pelvis being situated at the upper and lower parts of the renal sinus respectively. The lower pelvis was the larger of the two, and divided into three large primary branches which drained the lower two-thirds of the kidney; into the calyces of these three trunks six renal papillæ opened. The upper pelvis divided into two branches into which four papillæ opened. The two pelves were completely separate, although there was no corresponding division of the renal tissue, the upper and the lower parts of the organ appearing to be continuous.

Both ureters passed downwards and medially, and the ureter from the upper pelvis crossed the ureter from the lower pelvis at the pelvic brim on the right common iliac artery. They were both crossed by the spermatic vessels, while an accessory renal artery from the abdominal aorta passed behind them to the lower pole of the kidney.

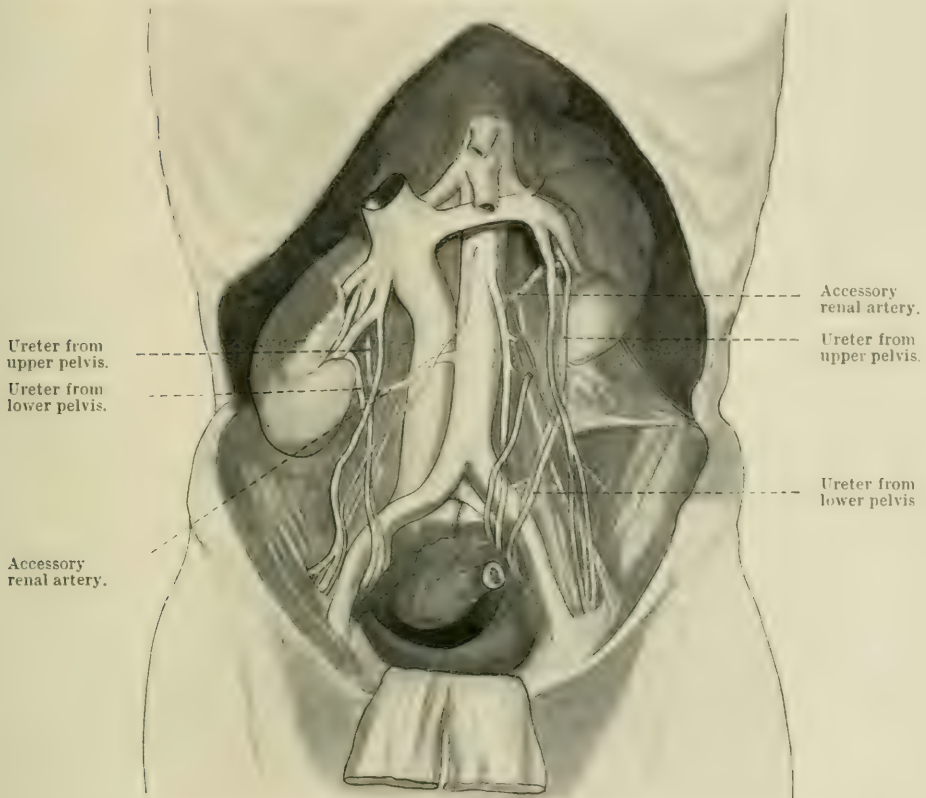


FIG. 1.—Dissection showing the relations of the kidneys, ureters, and blood-vessels.

The ureter from the upper pelvis was dilated at its lower end into an ampulla situated in the muscular wall of the bladder: this ampulla opened into the lateral angle of the trigone. The ureter from the lower pelvis opened on the mesial side of this ampulla, so that there was only one opening into the bladder on the right side. The length of the ureter from the upper pelvis was 24·5 cms., while that from the lower pelvis measured 21·5 cms.

On the left side the ureters opened by two separate orifices into the bladder: they were longer owing to the higher position of the kidney. The ureter from the upper pelvis measured 27·25 cms., that from the lower pelvis measured 24·5 cms. The division of the pelves resembled that on the right side: the upper pelvis divided into two branches, into the calyces of which three papillæ opened: the lower pelvis was the larger, as was the

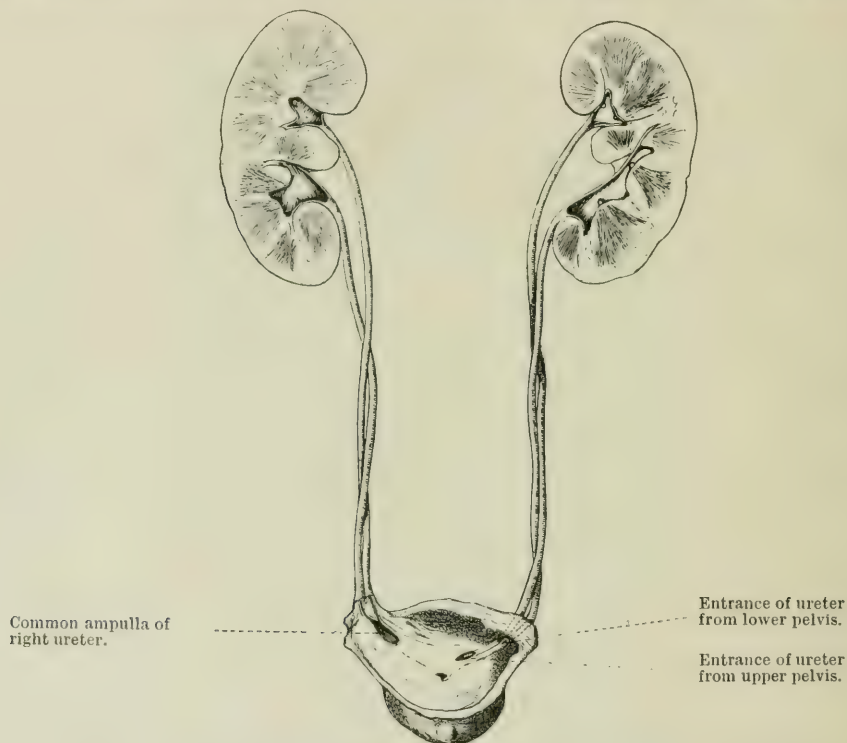


FIG. 2.—Dissection showing the mode of entrance of the ureters into the bladder.

case on the right side, and it divided into three main branches, five papillæ opening into the calyces of these branches. The ureters were crossed by the left spermatic vessels and the inferior mesenteric vein; the ureter from the higher pelvis opened on a papilla at the lateral angle of the trigone. The ureter from the lower pelvis opened higher up in the bladder postero-lateral to the ureter from the upper pelvis.

Each kidney received an accessory renal artery from the aorta; on the right side it was given off 4 cms. above the bifurcation of the aorta, and passed horizontally outwards in front of the vena cava inferior and split

into several branches which entered the inferior pole of the kidney. On the left side the artery was given off 6 cms. above the bifurcation of the aorta, and passed upwards and laterally to the hilum of the kidney, and was crossed by the left spermatic vessels. The right spermatic vein joined the right renal vein.

When a double ureter is unilateral the kidney having the two ureters is frequently the larger, and its inferior extremity descends to a lower level than normal and may occasionally be joined to the opposite kidney so as to form a horseshoe kidney. The occasional occurrence of symmetrical duplication of the ureter on both sides of the body is of importance in considering the causation of the condition, for it is unlikely that any local cause would act in a similar way on both sides of the body. This fact, along with the frequency with which other abnormalities are associated with the development of kidneys having double ureters, would lead one to infer that the abnormalities are of the nature of a so-called "germinal" variation, and would thus in all probability be hereditary, and would also come into the same category of variations as dichotomy of the digits or other parts of the body.

Pohlman (7) believes that incomplete double ureter is caused by the division of the renal bud beginning too early and the division extending beyond the pelvis into the segment belonging to the ureter; where more complete splitting of the renal bud occurs so as to be affected by the absorption of that segment of the Wolffian duct which lies between the opening of the ureter and cloaca, each ureter comes to have a separate opening into the cloaca; that is, a complete double ureter is formed.

Huntington (2), on the other hand, believes that the additional ureter is derived from an additional renal bud which arises from the Wolffian duct. Of these two theories Pohlman's appears to be the more satisfactory hypothesis. In other words, it may be stated that a more complete dichotomy or division of the renal bud takes place than normally occurs. If Huntington's view be correct, one would expect to find much more frequently than is the case, additional or supernumerary kidneys which would be completely separated off from the normal kidney, and often rudimentary in size. In the case I have described there was no distinct line of separation between the two parts of the kidney. This specimen seems to favour the view put forward by Pohlman rather than that by Huntington, as one would expect to see some indication of fusion, if the two parts were originally distinct.

The frequency of additional renal arteries in these cases may possibly be explained by the larger size and lower position of the kidney than is normal; there would thus be a greater liability for one of the more distal



branches of the embryonic renal plexus being retained. This view is supported by the frequency with which the abnormal renal artery when on the right side passes in front of the vena cava inferior.

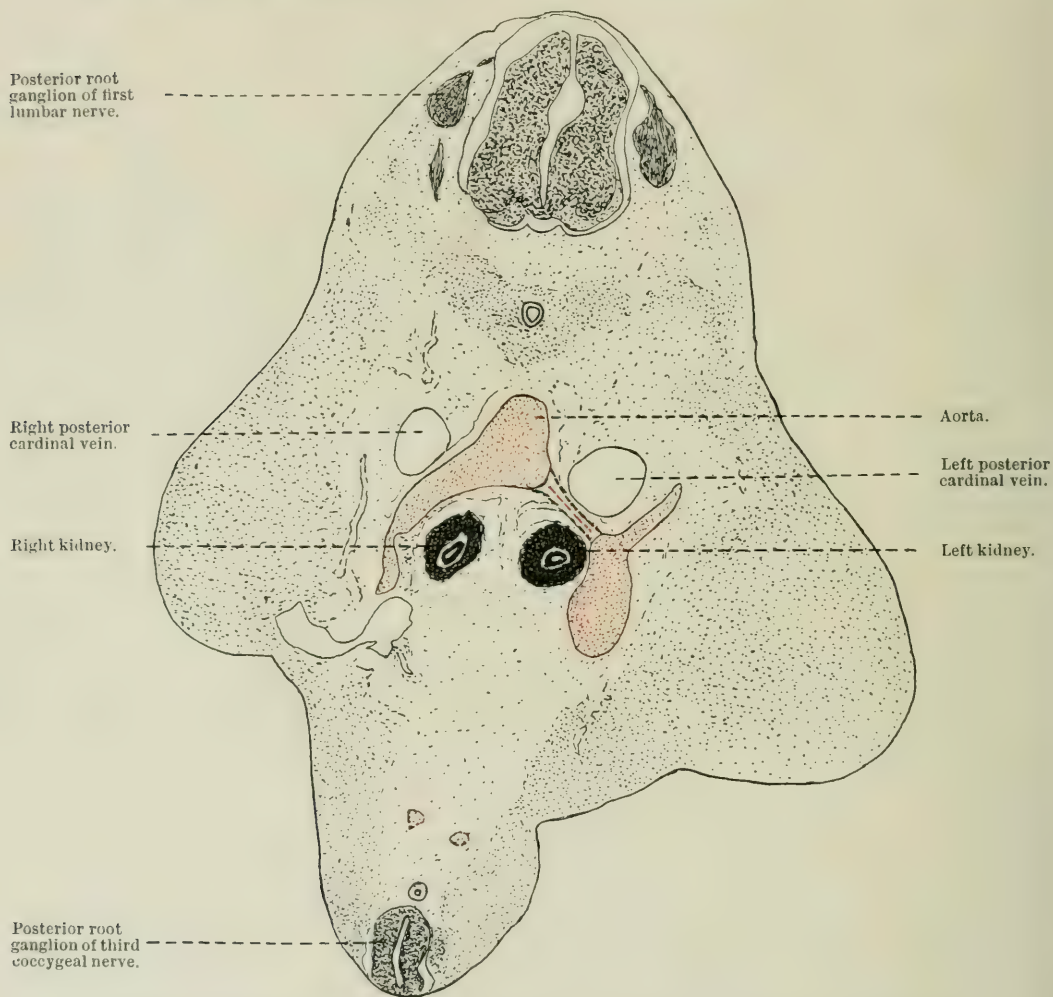


FIG. 3.—Transverse section of human embryo (10 mm. length), showing the two renal buds situated between the common iliac arteries, and ventral to the aorta and posterior cardinal veins.

The kidneys in a human embryo of 10 mm. lie ventral to and between the two common iliac arteries (see fig. 3), and also ventral and medial to the posterior cardinal veins; the arteries which the kidneys receive at

this stage also lie ventral to the posterior cardinal veins, and if they persist in the adult, would, when the right side is involved, lie in front of the vena cava inferior. In five cases of double ureter described by Abram T. Kerr (5) there were three in which additional arteries supplied the kidney having the double ureter, and in one of these the kidney received no less than four arteries, and discharged its blood by two veins into the vena cava inferior.

The arterial supply of the developing kidneys in a pig embryo of

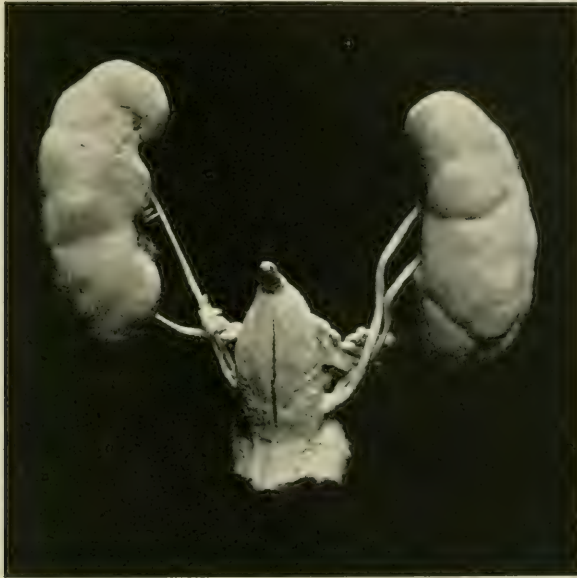


FIG. 4.—Specimen of bilateral double ureters from a female anencephalic fetus. The ureters on both sides opened by a common orifice into the bladder.

14 mm. has been described by Helmina Jeidell (4). At this stage the renal bud is surrounded by a capillary plexus derived from the inferior mesenteric and middle sacral arteries, and drained directly into the posterior cardinal veins or by the "vena advehentes" of the Wolffian body, and also by the inferior mesenteric vein. The plexus, which is difficult to recognise in ordinary serial sections, was demonstrated by her by means of injected embryos cut in sagittal sections 30  $\mu$  thick. These early vessels are replaced later by branches derived from the aorta, that of the right side passing behind the vena cava inferior. The earlier vessels usually disappear altogether, but may persist as permanent vessels of the kidney, as in the case I have described.

Although the renal bud when it first arises in the human embryo of three weeks, as is described by Ingalls (3), is given off from the lower end of the Wolffian duct opposite the second sacral vertebra, as soon as the embryo becomes fully curved the renal bud passes in a dorsal direction towards the level of the first lumbar vertebra which corresponds to the permanent level of the hilum of the kidney. Thus the arteries and veins formed in connexion with it at this period correspond in level to their position in the adult. When the embryo is afterwards straightened out the ureters become lengthened in a caudal direction, the kidneys themselves remaining in the position which they attain shortly after the period shown in the section of the 10-mm. human embryo.

Although rare, bilateral cases of double ureter have been recorded, and fig. 4 represents a specimen very similar to that which I have described. It was found by Dr R. J. Gladstone in an anencephalic foetus, and is preserved in the museum of the Middlesex Hospital. The ureters on both sides emerged from a separate renal sinus and united about 1 cm. above the bladder. On each side they opened by a common orifice in the usual situation at the lateral angles of the trigone. On both sides the ureter from the upper pelvis crossed in front of the ureter from the lower pelvis and was situated below the latter at its termination. Comparing this with the specimens described by Abram T. Kerr and myself, it seems usual for the ureter arising from the upper part of the kidney to end lower in the bladder than the ureter arising from the lower part.

In conclusion, I wish to express my thanks to Professor D. Waterston and Dr R. J. Gladstone for the assistance they have given me in writing this article.

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CONGENITAL VARIATION OF THE PECTORAL MUSCLES, WITH  
REPORT OF A CASE. By ELBERT CLARK. *From the Anatomical  
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Philippines, Manila.*

THE variation of the pectoral muscles in the present case is a slightly different one from any I have been able to find reported in the literature at hand. It is also of interest in that it furnishes evidence for an explanation of the origins of the variations of the pectoral muscles which, I believe, has not been offered by any of those authors who have reported "defect" of the pectoral muscles.

Absence of all or a part of the pectoralis major or of the minor, on one or both sides, is not of frequent occurrence, but, as has been pointed out by Bing<sup>1</sup> and others, variations occur more frequently in the pectoral muscles than in any other of the skeletal muscles. It is stated by Lengsfelder<sup>2</sup> that Hyrtl during his lifetime as an anatomist met with only two cases of congenital absence of the pectoral muscles. The literature relating to defect of the pectoral muscles up to 1902 has been carefully searched by Bing. He gives a rather complete bibliography up to that date. In all he was able to find reported 102 cases of absence or deficiency of the pectoral muscles. To this number, Wendel<sup>3</sup> adds 70 others. I have been able to find 10 cases not noted by either, and since 1904, 20 additional cases. This gives a total of 202 instances of defect of the pectoral muscles.

Regarding the frequency of defect in the skeletal musculature in general and the various combinations in which defects of the pectoral group occur, the following table taken from Bing furnishes an estimate:—

I. Pectorals	102 cases
Pars claviularis	6 cases
Pars sterno-costalis	20 "
Pectoralis major	3 "
Pectoralis minor	3 "
Pars clavicularis and pectoralis minor	1 "

<sup>1</sup> Bing, R., *Virchow's Arch.*, clxx., 1902, p. 175.

<sup>2</sup> Lengsfelder, M., *Wiener klin. Wochenschr.*, xv., 1902, p. 1306.

<sup>3</sup> Wendel, W., *Mitteil. a. d. Grenzgeb. d. Med. u. Chir.*, xiv., 1905, p. 456.



Pectoralis major and pectoralis minor . . . . .	26	cases
Pars sterno-costalis and pectoralis minor . . . . .	36	"
Pectoralis major and pectoralis minor (right), with	1	"
Pars sterno-costalis and pectoralis minor (left)		
Undetermined . . . . .	6	"
II. Cucullaris . . . . .		18 cases
III. Serratus anticus major . . . . .		14 "
IV. Quadratus femoris . . . . .		16 "
V. Omohyoideus . . . . .		8 "
VI. Semimembranosus . . . . .		7 "
VII. Abdominal muscles . . . . .		4 "
VIII. Gemelli . . . . .		4 "
IX. Deltoideus . . . . .		4 "
X. Latissimus . . . . .		4 "
XI. Sterno-cleidomastoid . . . . .		3 "
XII. Rhomboidei . . . . .		3 "
XIII. Supra- and infra-spinatus . . . . .		3 "
XIV. Biceps brachii . . . . .		3 "
XV. Small hand muscles . . . . .		2 "
XVI. Quadriceps femoris . . . . .		2 "
XVII. Platysma . . . . .		2 "
XVIII. Extensor carpi ulnaris . . . . .		2 "
XIX. Longissimus dorsi . . . . .		1 "
XX. Supinator longus . . . . .		1 "
XXI. Levator scapuli . . . . .		1 "
XXII. Intercostals . . . . .		1 "
XXIII. Face muscles . . . . .		1 "
XXIV. Gastrocnemius . . . . .		1 "
XXV. Subclavius . . . . .		1 "
XXVI. Triceps brachii . . . . .		1 "
XXVII. Brachialis int. . . . .		1 "
XXVIII. Glutæi . . . . .		1 "
XXIX. Extensor digiti V.-proprius . . . . .		1 "
XXX. Extensor digitorum sublimis . . . . .		1 "
XXXI. Stylohyoideus . . . . .		1 "

Of the 214 cases of absence of skeletal muscle in this table, 102, or nearly one-half, were cases of absence of the pectorals. This is a relatively high proportion. However, as Bing points out, this proportion is too high, and for at least two reasons: (1) absence of a pectoral muscle is so easily detected in the clinic; and (2) on account of a somatic and thoracic deformity a physician is nearly always consulted. Such is not the case with the smaller and less apparent muscles. Yet, making allowance for this, there probably remains a large percentage for the pectorals. "Regarding the absolute frequency of 'Brustmuskelfecte,' the following data of Schlesinger's will give an idea: he saw in Schrötter's clinic in

Vienna among a sick list of 54,000 patients 5 cases, an average of about 1 in 11,000" (Bing).

An analysis of the cases of congenital absence of pectoral muscles will substantiate the statements of Lengsfelder: "It is further the most frequent combination, that the sterno-costal portion of the m. pectoralis major and the pectoralis minor are absent," and also, "Bilateral defect, isolated absence of the clavicular portion, isolated absence of m. pectoralis minor, are rarities." Further, as noted by Wendel ('05), "In the literature there is found only a single case (observed clinically) of bilateral congenital Brustmuskelfekt." Of all the cases of congenital absence of pectoral musculature reported up to 1911 there is only one instance in which heredity as a causal factor might be considered. This is, I believe, the only instance in which absence of a pectoral muscle has occurred in more than one member of a given family. Greif reports congenital absence of the pectoralis major and minor (left) in his father and brother, and a poorly developed pectoral musculature in himself. As regards other muscles, Fürstner<sup>1</sup> reports congenital quadriceps muscle defect in two brothers.

In many of the cases reported pectoral muscle defect has been accompanied by either extensive congenital malformations and deformities of neighbouring parts, or pronounced pathologic lesions in the skeleton and skeletal musculature. The number of instances of simple congenital defect or absence of the pectoral muscles is thus reduced. An analysis of the literature seems to show that congenital deformity of the pectoral group does occur most frequently in conjunction with more or less extensive malformations of neighbouring structures. For instance, scarcity of hair, fascia, and fat in the pectoral region and axilla, displacement and atrophic condition of the mammary gland, tightness of skin, defective development of the ribs and intercostal muscles, and of the neighbouring shoulder muscles on the affected side, singly or in various combinations, are reported as most frequently associated with congenital defect of the pectoral muscles.

In so far as I am able to determine, the clavicular portion of the pectoralis major was present in nearly every congenital case, and was even somewhat hypertrophied. In some cases the deltoid also appeared hypertrophied. Those of the living subjects who were in good physical condition showed no inconvenience or awkwardness on account of the muscular deficiency. Thus Burke's patient (absence of sterno-costal portion of pectoralis major and all of the pectoralis minor on the left side) was a good baseball pitcher (left-handed), the patient of Bruns<sup>2</sup> was one of the

<sup>1</sup> Fürstner, *Archiv f. Psych.*, xxvii, 2, 1895, p. 607.

<sup>2</sup> Eulenberg, A., *Deut. med. Wochenschr.*, xxxv., 1877, p. 413.

best "turner," that of Eichhorst<sup>1</sup> "sächträger," the student of Fränkel<sup>1</sup> "ein ausgezeichneter Fechter," and Stintzing's<sup>2</sup> patient (defect left) fenced left-handed.

Huntington<sup>3</sup> has traced the phylogeny of the pectoral muscles through the primates, and finds that these muscles present a great many variations in the different groups. Both pectoralis major and pectoralis minor show a great tendency to vary. The most common variations, however, are those of the pectoralis abdominalis, both in its relation to the pectorales major and minor and to the axillary arch. As the pectoral muscles are among the last to be acquired, it is not surprising that they show so many variations in man. On the other hand, that portion which is acquired last (*i.e.* the clavicular portion of the pectoralis major) shows the fewest variations. Huntington has also shown that in the primate series the pectoral muscle mass is early differentiated into superficial and deep layers of "sharply defined individuality," corresponding to the pectoralis major and minor in man respectively. Thus isolated absence of the pectoralis minor is not readily to be explained as a reversion. That congenital pectoral muscle defects in general do not represent reversions is made probable by the striking absence of bilateral defects. As Wendel (1905) points out, congenital pectoral muscle defects are (with a single exception) always unilateral.

The present variation (left side) was observed in a muscular, well-developed male Filipino subject in the dissecting-room. The skeletal musculature was well developed throughout, and no other variations of the muscles were observed.

*Right.*—The pectoralis major on the right side is well developed and of normal appearance. There is no distinct line of separation between pars clavicularis and pars sterno-costalis, and the pars abdominalis (not illustrated) is small. The muscle arises from the medial two-fifths of the clavicle, the capsule of the sterno-clavicular articulation, from the anterior surface of the sternum for its entire length, and from the anterior surfaces of the medial ends of the 1st to 7th costal cartilages. The small pars abdominalis arises from the anterior leaf of the vagina m. recti abdominis. Insertion: crista tuberculi majoris humeri.

The pectoralis minor arises by fleshy and fibrous digitations from the 2nd to 5th ribs inclusive and the fibrous sheaths of the adjoining intercostal muscles. It is inserted into the processus coracoideus scapulæ, some fibres going over into the capsule of the shoulder articulation.

Innervation of both muscles: nn. thoracales anteriores.

<sup>1</sup> Cited by Lengsfelder (2).

<sup>2</sup> Cited by Bing (1).

<sup>3</sup> Huntington, Geo. S., *Amer. Jour. Anat.*, ii, 1903, p. 157.

*Left.*—The pectoralis major on the left side consists of two parts: a large, apparently hypertrophied pars claviculæ and a small pars sternocostalis. These two portions are well separated from each other. The pars claviculæ arises from the medial half of clavicle, with a few fibres



FIG. 1.—On the right side there is a well-developed pectoralis minor. The pectoralis major is a broad flat muscle not separable into clavicular and sterno-costal portions. The pars abdominalis has been removed. On the left the pectoralis minor is entirely wanting. The pars claviculæ of the pectoralis major appears hypertrophied. The small pars sternocostalis is likewise thick, and the fibres run in coarse bundles. Its fleshy origin does not extend below the 2nd costal cartilage. The left mamma is over the 4th intercostal space.

also from the capsule of the sterno-clavicular articulation. The pars sternocostalis arises from the anterior surface of the upper part of the sternum between the incisura claviculæ and the 3rd sterno-costal



articulation, and from the anterior surface of the medial 2.5 cm. of the 2nd costal cartilage. The two portions are inserted by a common tendon into the crista tuberculi majoris humeri. The pars sterno-costalis is 5.5 cm. in its greatest breadth and 2 cm. in its greatest thickness. The muscle fibres in both pars clavicularis and pars sterno-costalis run in coarse bundles. The pars sterno-costalis courses lateralward, the lower half of the fibres taking a somewhat spiral course, to form the posterior portion of the tendon of insertion. The fibres of the pars clavicularis pursue an almost parallel course, slightly converging laterally and running anterior to those of the pars sterno-costalis to form the anterior portion of the tendon of insertion. The whole muscle is enclosed in a very tough, thick fascial sheath. This sheath is more abundant over the pars sterno-costalis. Innervation: nn. thoracales anteriores.

*Pectoralis minor*.—No trace of a pectoralis minor can be found. The fascial sheath above referred to is especially strong and heavy in the location of the absent pectoralis minor. It is continuous superiorly with the costo-coracoid membrane, being attached to the upper two ribs, and inferiorly extends into the sheath of the serratus anterior and under the mamma. Laterally it becomes very thin and goes over into the axillary fascia. No muscle fibres nor any indication of a degenerated muscle can be found in this fascia.

On the left side there is no perceptible deficiency of fat, fascia, or hair; the skin is not closely adherent to the thorax, and there is no defective development of the ribs or intercostal muscles. The papillæ are approximately symmetrical in position.

The variation in the present subject differs from the great majority of those found in the literature in that there is a total absence of the pectoralis minor and only a partial absence of the pars sterno-costalis of the pectoralis major. From the normal appearance of all the neighbouring structures and the entire absence of any trace of muscle fibres of the pectoralis minor, the conclusion is justified that the condition is congenital.

Before attempting an explanation of congenital pectoral muscle defect, a few remarks concerning the development of the pectoral muscles are necessary. W. H. Lewis<sup>1</sup> has shown that:—

“The pectoral premuscle mass from which both the mm. pectoralis major and minor arise is clearly indicated in a 9-mm. embryo. It lies in the lower cervical region on the medial side of the arm bud. This premuscle mass is widely continuous with the arm premuscle sheath, and lies almost entirely anterior to the 1st rib. In an 11-mm. embryo it reaches about

<sup>1</sup> Lewis, W. H., in Mall and Keibel's *Manual of Human Embryology*, Philadelphia, 1910, vol. i. p. 487.

the level of the 3rd rib, but the two muscles still form a single columnar mass attached to the humerus, to the coracoid process, and to the *clavicular* rudiment. As the mass differentiates, it flattens out and extends caudo-ventrally to the region of the distal ends of the upper ribs. In a 14-mm. embryo the caudal end of the muscle has extended near to the tip of the 5th rib and the muscle has begun to assume more the adult form, with fibres arising from the upper five ribs and sternal anlage as well as from the clavicle. At this stage the proximal portion of the muscle has split into the major and minor portions, the one attached by tendon to the humerus and the other to the coracoid process. Both muscles fuse together near the costal attachments. In a 16-mm. embryo the two muscles are quite distinct, the pectoralis major now extending to the 6th rib and showing a distinct cleavage between the costal and clavicular portions. The pectoralis minor has now its distinct attachment to the 2nd, 3rd, and 4th ribs."

Regarding an embryological explanation of the congenital absence of the pectoralis minor and the pars sterno-costalis of the pectoralis major there are three possibilities:—

1. These structures may fail to develop in the embryo.
2. There may be a formation of the anlage and a partial development of the muscles, but, failing to become attached to the bones, part of the muscles subsequently atrophies.
3. That portion of the premuscle mass which in normal development goes to form the pectoralis minor and two portions of the pectoralis major may more or less completely fail of subsequent differentiation into its separate parts.

According to Lewis,<sup>1</sup> "the pectoralis major muscle (*i.e.* pars clavicularis and pars sterno-costalis) arises, in common with the minor, from a premuscle tissue which is located for the most part above the 1st rib." It early forms an attachment to the clavicle. "It gradually migrates or shifts to the costal region, as has already been noted by Dr Mall."

With the exception of those cases involving extensive malformations of the neighbouring structures, the instances in which there is an entire absence of all the pectoral musculature on either one or both sides are extremely rare. These facts make it probable that the first consideration (*i.e.* that there is lack of development of the pectoral musculature in the embryo) is responsible at most for only a very small percentage of pectoral muscle defects.

Regarding the other two possibilities—(2) failure of attachment and subsequent atrophy of the pectoralis minor and pars sterno-costalis of

<sup>1</sup> Lewis, W. H., *Johns Hopkins Hospital Bulletin*, xii., 1901, p. 172.

pectoralis major, and (3) lack of complete differentiation—it is probable that both are separately concerned in producing congenital pectoral muscle defect. However, the evidence available is not sufficient to indicate a preference. That there may occur in some cases an incomplete differentiation is indicated by the fact that absence of the pectoralis minor and pars sterno-costalis of the pectoralis major is usually associated with a hypertrophied pars clavicularis, which latter, so far as histologic examination has been made, contains an increased number of muscle cells—more than in any other skeletal muscle. In this case we might also expect a deficiency of fascia in the pectoral region of the affected side, since, the thoracic portions of the pectorals failing to migrate ventro-caudally, the fascial tissue would likewise not be brought down. The migration ventro-caudally of this pectoral muscle mass would probably also have an influence on the overlying portions of the skin, and in the event of no migration the mammary gland would be located at a higher level and more laterally. These two conditions have been most frequently described as accompanying congenital absence of the pectoralis minor and the pars sterno-costalis of the pectoralis major.

The second possibility is essentially that advocated by Lewis: "It would seem that in the conditions existing between an embryo of 9 and 11 mm. in length might be found a partial explanation of such varieties as absence of the sterno-costal or clavicular portions and of the pectoralis minor with the sterno-costal portion. We have here a condition in which the clavicle is absent and no attachment to the ribs exists. The subsequent attachment to one or the other might not occur and that portion of the muscle be found wanting in the adult. With absence of the sterno-costal portion would be associated that of the pectoralis minor owing to their early fusion."<sup>1</sup>

When the differentiation takes place and there is a failure of attachment to the thorax and a subsequent atrophy of the muscle mass, we would expect at least the normal amount of fascia and fat, a normal position of the mamma, and that the deformity might not be apparent in early childhood. These conditions have also been frequently met with. This hypothesis would also offer an explanation for the loose fold of skin forming the anterior axillary wall and extending ventro-caudally to the mamma, and termed by several authors "Flughaut." Of the cases reported up to 1907 Loening says: "In the location of the absent breast muscles

<sup>1</sup> A suggestion of Bing which may account for the arrest of migration and a consequent failure of attachment of the pars sterno-costalis and the pectoralis minor is perhaps worthy of notice. In his opinion the chin pressing against the anterior thoracic wall during intra-uterine life would account for absence of these muscles on that side. It is easy to suppose that such an impediment might prevent the caudo-ventral migration of these parts



there often occurred stretched out between the thorax and the upper arm a skin fold (Flughaut) which consisted of a fairly compact fibrous tissue, for the most part enclosing within itself no rests of muscle substance."

A discussion of the underlying factors which are responsible for a failure of formation of the pectoral muscle mass, a failure of its differentiation, or the failure of the differentiated muscles to make attachment, are beyond the scope of this paper.

In the present case, in which there is an absence of the pectoralis minor and the greater portion of the pars sterno-costalis of the pectoralis major, there is, I believe, only one plausible explanation: namely, that the condition is congenital, and that the pectoralis minor, failing to find its costal attachment, underwent degeneration, and that the pars sterno-costalis of the pectoralis major did not make attachment below the 3rd costal cartilage.

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<sup>1</sup> This list of references includes only those which are not given by Bing (1) and Wendel (3). Some of them have been collected from other articles, from the *Index Medicus*, and from the Index Catalogue of the Library of the Surgeon-General's Office, United States Army.



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# THE HUMAN STOMACH AND THE CANALIS GASTRICUS (LEWIS).

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## INTRODUCTION.

So much has been written about the normal human stomach and its shape, that one hesitates to embark upon a subject to all appearances so well worn.

It has been a commonplace of comparative anatomy for many years that ruminant animals possess the power of swallowing fluid directly into the pyloric portions of their stomachs without its mingling with the more solid food in the cardiac sacs. Later, it was shown that carnivorous animals—notwithstanding their simple, single-chambered stomachs—possess the same faculty. Since that time, the minds of anatomists have been much exercised in a desire to prove or disprove that the same is true of human beings. Waldeyer (1), who wrote an exhaustive paper in support of this theory and called the potential passage the “Magenstrasse,” suggests that a solution to the question should be readily found by means of X-rays. This idea had already suggested itself to me, and the investigation was begun some eighteen months ago. So far as I am aware, no one has attempted this work, the results of which are here set down.

## COMPARATIVE ANATOMY.

A brief sketch of the comparative side of the subject may be of help to the reader. Ruminant animals swallow their food, as they graze, into the first and second stomachs (rumen and reticulum). Here it is stored until a time favourable for mastication presents itself. A suitable quantity is then returned to the mouth by a sharp contraction of the abdominal muscles. This is the method of return of the food in ruminating human

beings (Brockbank (2), and Lemoine and Linossier (3)), as antiperistalsis is unknown in the œsophagus. After the bolus has been well masticated by the familiar side-to-side movement of the jaws, it is again swallowed. It does not, however, return to the saccular first or second stomachs, but this time it passes on to the third stomach (psalterium), whence it is rapidly expelled into the fourth (abomasus) and so into the duodenum. The passage of the soft, chewed bolus into the pyloric portion of the ruminant's stomach is accomplished by means of the sulcus salivalis (Retzius) or

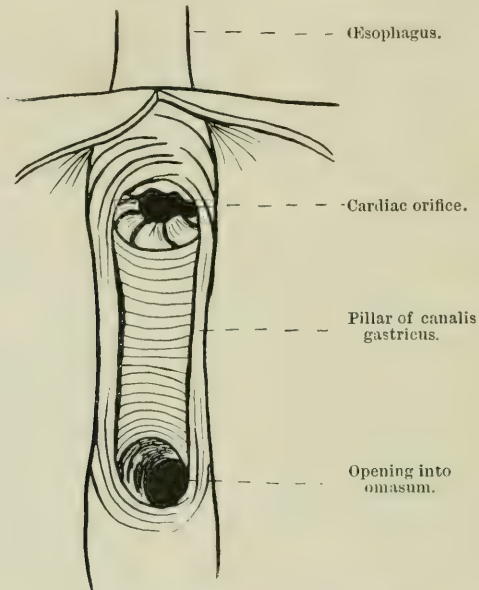


FIG. 1. —The sulcus œsophagus (canalis gastricus) of the ruminant. Mucosa stripped off to show muscular fibres. (After Carpenter.)

canalis gastricus of Lewis (fig. 1). This canal varies in completeness. In some animals it is a veritable tunnel, the lips of which have to be forcibly separated in order to view its interior. The longitudinal muscle fibres contained in its borders, by their contraction, approximate the lips of the canal and also shorten it. Thus Home (4) described the ox's stomach: "When the food is swallowed the second time, the orifice of the third cavity is brought forwards by the muscular bands which terminate in it, so as to oppose the end of the œsophagus and receive the morsel without the smallest risk of its dropping into the second."

In suckling ruminants the milk flows directly into the psalterium and abomasus (Owen (5)). In animals with simpler stomachs the following

observations have been made: Cohnheim (6) found that, in the dog, water did not mix with the general food in the stomach, but passed on as it was to the pylorus—an occurrence at which he was greatly surprised. The dog's stomach is to all appearances quite innocent of any groove or canal along the lesser curvature. I have found this to be equally true of the horse's stomach, yet Colin (7) by the most exhaustive experiments on the live horse came to the same conclusion, namely, that water passed straight on into the pyloric portion, its descent being made along the lesser curvature. Smith (8) is of the same opinion. Since neither of these simpler-stomached animals has any salient canal, this selective action must be a purely physiological one, and probably due to specialised contraction of a portion of the gastric musculature.

#### ANALYSIS OF EXISTING EVIDENCE OF THE PRESENCE OF THE CANALIS GASTRICUS IN MAN.

Under the name of *canalis gastricus*, Lewis has called attention, in a recent and wholly admirable paper (9), to a canal along the lesser curvature of the human foetal stomach. It is surprising that it has received so little attention in England, as it has from time to time called forth considerable discussion on the Continent. Lewis gives some excellent reconstruction models in his paper, and describes the channel as follows:—It “follows the lesser curvature, appearing as a groove when seen from the inside of the stomach. It suggests a continuation of the oesophagus, split open towards the gastric cavity . . . an open canal which . . . may become a tube during its physiological activity, by the approximation of its lips” (*loc. cit.*, p. 486).

His own view is that in the human embryo it is a definite, epithelial structure, since it appears before the oblique muscle fibres, at whose door the responsibility of forming the canal had been laid by Kaufmann (10). Viewed from the inside in Lewis's model of the stomach of a 44·3-mm. embryo (fig. 10, *loc. cit.*), the canal may be seen as a depression along the lesser curvature. Similar figures are given without any comment by Broman (11), as pointed out by Lewis.

Keith and Jones (12) remark on a very definite canal running from the opening of the oesophagus to the pyloric antrum along the human lesser curvature. This they thought was probably for the conveyance of fluids. “Such a groove with vestigial ridges can certainly be detected in the human foetal stomach.”

It is, however, doubtful whether such appearances are due to more than the fact that the stomach develops from a very localised portion of the primitive foregut, this tube remaining more or less unchanged along the



lesser curvature. All gross evidence of this canal rapidly disappears, but Lewis believes that it persists long enough to influence the arrangement of the oblique muscle fibres. There can certainly be no physiological action, unless there be an anatomical mechanism underlying it, so that, although the canal has gone, it may well be that the muscular fibres are so disposed that they are able to produce a groove or gutter again at need.

Retzius (quoted by Lewis) supports the existence of the canal as follows:--

"The upper portion of the oblique fibres of the human stomach serves to form a trough along the lesser curvature, which, under the control of the motor nerves, becomes more or less closed; along this path possibly fluids and soft things, saliva, etc., may proceed directly from the œsophagus to the pars pylorica, passing by the cardiac portion."

Waldeyer (1), as mentioned above, describes a very definite "Weg" or "Strasse" along the lesser curvature which conveys ingesta chiefly because of the arrangement of the folds of mucous membrane (to be referred to shortly) and of the upright position of the organ. Of exactly how much value this observer believes the oblique muscle to be, it is difficult to judge from his writings, though Lewis quotes him as an adherent to this theory. Hasse and Strecker (13) have gone so far as to name the anterior and posterior lips of the gastric canal *plica hepatica* and *plica aortica* respectively, joined together above by the *plica cardiaca*. Their evidence, however, does not bear close investigation in the light of modern knowledge of the shape of the stomach, for they have based their description on the impressions made upon the stomach by neighbouring organs, and their figures of the viscus show a much indented and improbable organ. Strecker, however, in an independent paper, seems to favour the musculature rather than folds produced from without as a canalive agent. Kaufmann (10) is a strong upholder of the muscular theory, and believes that the oblique fibres are capable of temporarily converting the groove into a canal.

Ernst (15) has pointed out that the stomachs of people who have swallowed corrosive fluids show most destructive lesions along the lesser curvature.

Existing radiographic evidence of the gastric canal is to be found only indirectly, as workers in this subject appear to be quite ignorant of such a possibility. Barelay (16) figures bismuth entering the stomach and being closely confined to the lesser curvature (*loc. cit.*, fig. 15), and Gray (17) draws attention to the radiograms of Ribas y Ribas (18) as proof of the existence of the remains of the primitive foregut. These photographs (*q.v.*, Nos. 15-17) are certainly suggestive, but are open to criticism

(*vide infra*), as the bismuth may simply be taking the shortest route to the bottom of the stomach, towards which it is progressing in a uniform



FIG. 2.—Skiagram of the almost empty normal human stomach. A thin stream of bismuth occupies the position of the canalis gastricus at the lesser curvature. Note the essentially vertical position of the stomach, and the obliquity and narrowness of the terminal œsophagus. A peristaltic wave is coursing along the pars pylorica, involving its whole diameter.

stream. Hartung, in a very recent paper, says: "The first few mouthful seem to follow in groove arrangements along the lesser curvature, called the 'Magenstrasse' by the Germans."

From the clinical side, most surgeons are familiar with what we may term selective vomiting, *e.g.* the vomiting of bile instead of the food which has just been taken. This is very puzzling, unless we credit the stomach with the power of cutting off a portion of its interior from the general cavity.

#### EVIDENCE OF THE PRESENT INVESTIGATION.

This will be best considered under two heads—

A. Radiographical.

B. Anatomical.

This is strictly the order in which the investigation was carried out, for had not the author been considerably encouraged by his X-ray findings he would hardly have attempted to find an anatomical mechanism which would explain the appearances.

#### A.—Radiography.

Some twenty-two normal people were investigated through the kindness of Dr Knox. The patients were screened whilst swallowing a mixture of bismuth oxychloride and milk of the consistency of thin cream. The first point was to find whether the fluid, as it entered the stomach, spread out over the walls or was confined to the lesser curvature. Judging by the extreme obliquity at which the œsophagus enters the stomach (see fig. 2), the former of these two possibilities would be expected. Such, however, is not the case. In eighteen out of the twenty-two cases (roughly 82 per cent.) the fluid was confined to the lesser curvature. In the other four cases it spread rapidly over the sides of the stomach, but these stomachs were atonic, though healthy—a combination by no means rare.

It is easy to watch the descent of the fluid by means of the fluorescent screen, but it is a difficult matter to obtain a satisfactory photograph, owing to the difficulty of judging the psychological moment at which to take the plate. One cannot use the screen and the photographic plate at the same time.<sup>1</sup> There were great variations in the time at which the fluid actually entered the stomach and then descended through its body. The variation in the time of entry is obviously due to the nervous control of the cardia (Cannon (20), *loc. cit.*, p. 34), for the time occupied in the traversing of the œsophagus is fairly constant. The time difference in the descent through the stomach is well known to radiographers, and usually ascribed to cohesion of its walls (Bythell and Barclay (21), *loc. cit.*,

<sup>1</sup> L. G. Cole has recently devised a cinematograph X-ray table by means of which this is possible. This marks a great advance, but is, of course, expensive. See "Roentgenocinematography of the Stomach and Cap," *Amer. Journ. Roentgenology*, March 1914.

p. 86; also Hertz), or difference in the specific gravity of the bismuth.<sup>1</sup> With this view I cannot agree, believing it to be more probably due to a neuro-



FIG. 3.—Skiagram of the almost empty normal human stomach. A column of bismuth is entering the stomach by the canalis gastricus. The incisura angularis is well shown. A deep wave of contraction involves the pars pylorica. Coin indicates umbilicus.

muscular mechanism controlling the action of the oblique muscle fibres—a point to be referred to later.<sup>1</sup> A few good photographs were obtained,

<sup>1</sup> I find that Brauening (22) suggests that there is an cesophageal reflex that increases tone in the gastric musculature and may delay descent. If we admit the existence of a gastric canal, this action becomes purposive.



and to three of these (figs. 2, 3, and 4) the reader is referred. I wish to call attention particularly to figs. 2 and 3, which are photos of the practically empty human stomach. Two mouthfuls of the bismuth cream were given to map out the greater curvature at its lowest point, and the exposure made immediately after the patient had swallowed the third. It will be seen that a small quantity of bismuth is at the bottom of the stomach, a rather less quantity at the cardia, whilst joining the two together is a narrow stream of bismuth strictly confined to the lesser curvature. There are three possible explanations of these appearances:—

- (1) That the fluid has fallen by gravity down the nearest wall, by the most direct path;
- (2) That the stomach is tightly contracted down, so that its lumen is no larger than will allow of the passage of the bismuth in a thin stream;
- (3) That it is lying in a physiological canal or gutter—the *canalis gastricus*.

That gravity plays an important part in the descent of the bismuth down the lesser curvature it would be foolish to deny. There are probably no peristaltic waves along this curvature (see figs. 2 and 8). The point at issue is whether the cream is falling down a specialised channel cut off from the remainder of the stomach, or is merely taking the shortest path to the bottom of that organ, as it would if led into an inert bag. The fact that there is a considerable quantity of cream held up at the cardia is strong evidence against this first theory. Had the whole of the fluid fallen to the bottom of the stomach, as it may be seen to be doing in Ribas y Ribas skiagrams, this explanation might have had more than a little of verisimilitude. But a quantity is so definitely shown in fig. 2 to be held up just below the cardiac orifice that such an explanation seems to me improbable.

The second possibility merits careful consideration. Hertz has described the normal empty stomach as being contracted down like a piece of small intestine, its cavity being potential only, and suitable for representation in linear fashion (*Quart. Journ. of Med.*, 1910, fig. 5). It might be argued on this view that figs. 2 and 3 simply show canalisation of the contracted viscus. With this view I am quite unable to agree, though his teaching has become more or less the standard one, and his drawings accepted for students by Waterston in the latest edition of Cunningham's *Anatomy* (*q.v.*, fig. 923). There are two great objections, however, to the Hertz doctrine. It is difficult to believe that the long smooth muscle lengths of the stomach are ever capable of such shortening as would be necessary to reduce its lumen to zero, however much they were rearranged (Müller (23)).

Perhaps the pyloric canal, the last two inches or so of the expulsive portion of the stomach and that most nearly approaching the small intestine in



FIG. 4.—The normal human stomach half full. The track by which the bismuth has entered is clearly seen at the lesser curvature. A few flakes of bismuth map out the greater curvature. Some of the bismuth had passed on into the small intestine before the cream was given.

calibre, can contract down to a state approximating to that assigned by Hertz to the whole stomach. One can well believe that the stomach has only a potential cavity, owing to approximation of the anterior and posterior walls. The writer wishes to be quite explicit about this. He

does not believe the stomach to be a flabby bag, with its walls in apposition, like the rubber hot-water-bottle stomach (so to say) of all but recent anatomy. Nor is fig. 5 quite satisfactory in showing a stomach of average outline *in vivo*. The normal lies somewhere about midway between this and the condition described by Hertz.

Further, in fig. 2 it will be noted that the bismuth descends excentric-

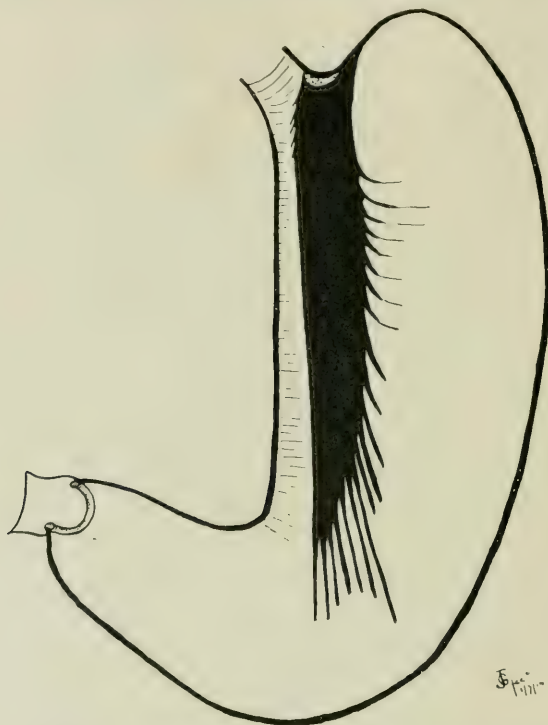


FIG. 5.—Diagram of the vertical portion of the oblique muscle of the stomach, which forms an inverted U over the viscus. By its contraction it can cut off a passage along the lesser curvature. (Camera-lucida drawing of stomach in its normal upright position.)

ally from the extreme left-hand margin of the top shadow, as if it was only at this point that there is a way of escape. If Hertz's theory were correct, all the shortening must occur towards the lesser curvature, so as to make excentric the lumen of the stomach. His diagrams (fig. 3, *Brit. Med. Journ.*, 28th Sept. 1912, and fig. 5, *Quart. Journ. of Med.*, July 1910) show that he has not thought this to be the case.

An attempt to prove the existence of the canal radiographically was made by pressure over the partly filled stomach, with doubtful result. (It

was thought that the bismuth might ascend it on such pressure.) But it seems to me very probable that the canal is only segregated by the stomach for a few seconds at a time when soft things are entering, so that this cannot be accepted as evidence against the existence of the canal.

The third possibility is that the stomach is making a co-ordinated effort to direct the fluid into a channel at its lesser curvature. This must be accomplished by means of specialised bands of muscle, and before this theory can be accepted it must be shown that there is in the stomach a mechanism capable of such an action. With this end in view, the writer proceeded to the second part of the investigation, and this is now put forward.

### B.—*Anatomical.*

The well-known description of the gastric musculature by Birmingham (24) is of little or no value. For he had figured the stomach as a horizontal organ with fundus to the right and on the same level as the pylorus (*vide* Cunningham's *Anat.*, fig. 926, and *loc. cit.*), a belief in which he was joined by Willis (25) in 1674, and apparently also among others by Paterson (26) in 1913. Cunningham's (27) dissection (*loc. cit.*) by removal of the mucosa is very valuable, for here the stomach is drawn in its true vertical position. The writer investigated five human stomachs after the method of Cunningham, the stomachs first being hardened in formalin after having been arranged with the lesser curvature vertical and the fundus upwards (fig. 5). Reference to this figure shows the disposition of the inner or oblique coat. This runs vertically down the whole length of the body of the stomach. It is a narrow, flat band, coursing from the incisura cardiaca, which fold it produces, to the commencement of the pars pylorica. I have not found it turning round the incisura angularis to run towards the pylorus, as figured by Cunningham. The fibres are perpendicular, the outermost curving outwards and gradually becoming lost by mingling with the circular coat. The right margin of this muscle band is sharply defined, and has no deep connexions. It can be readily dissected up from the circular coat beneath it. This band forms an inverted letter U over the stomach. And it seems reasonable that by its contraction it will cause more or less of a cutting off of a canal along the lesser curvature.

From my own dissection of the horse's stomach (to which animal Professor Keith kindly called my attention) I was unable to find any muscle other than the oblique coat which could cut off a canal for fluids. The disposition of this muscle in this animal looks to be more unpromising for such an action than it does in the human, yet its physiological presence is undoubted.



It was not until my dissections were nearing completion that I became acquainted with the painstaking work of Forsell (28), who, for a different purpose, has correlated the musculature of the stomach with X-ray findings. This author attaches great importance to the oblique layer, which he figures as being arranged in definite muscle slings (fig. 6). This division appears to me rather didactic, for I have been unable to find anything which

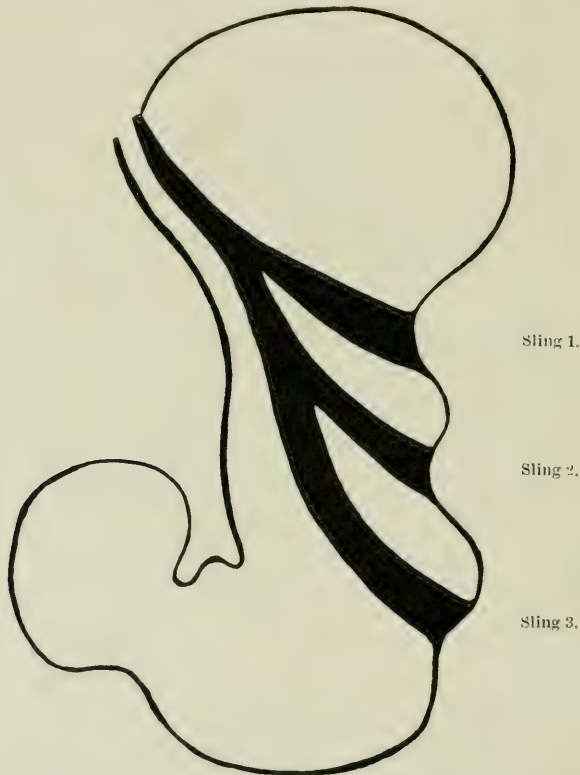


FIG. 6.—The oblique muscle of the stomach (vertical portion), to explain fig. 8, and draw attention to a muscle the importance of which has been greatly underestimated. Note the muscle slings. (After Forsell.)

distinguishes one band of this muscle from the rest of it; the whole forms one homogeneous sheet. However, Forsell does good service when he calls attention to the importance of the oblique coat and its relations to the circular. Thus, the bismuth which was so constantly held up just below the cardiac orifice (*e.g.* see fig. 2) is probably held there by contraction of the upper oblique fibres, whilst the canalis gastricus is shut off by contraction of the vertical parallel fibres (see fig. 5). This seems to me much

the most rational explanation, as a moderate shortening would be sufficient to produce both these effects. Whilst an excessive contraction would be needed of the circular fibres if they were the causal factors, such a cutting off is facilitated by the arrangement of the mucous membrane in the

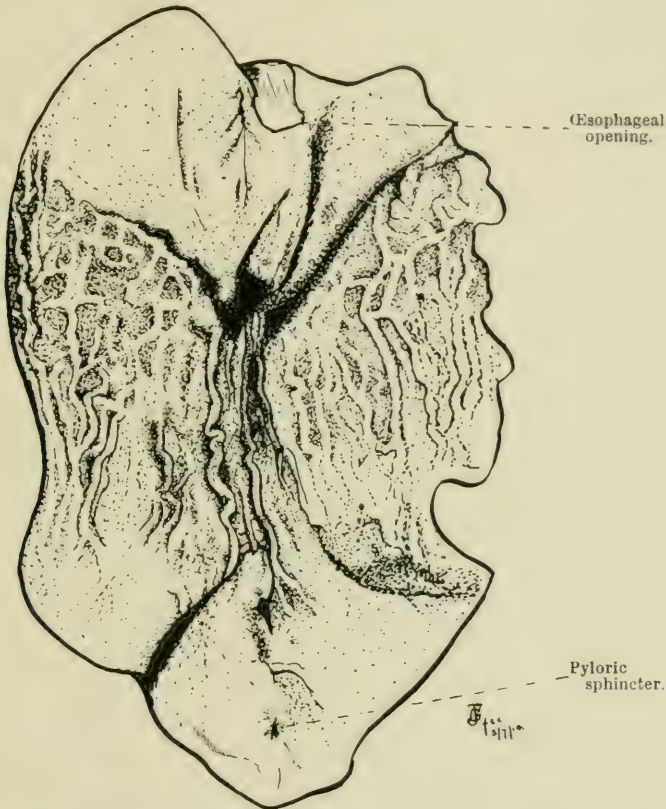


FIG. 7.—The human stomach cut open along the greater curvature almost to the pylorus, to show the mucous membrane. Note the arrangement of the longitudinal plicæ without anastomoses at the lesser curvature, compared with the network over the greater part of the body of the stomach. (Camera-lucida drawing.)

interior of the stomach, which lies in longitudinal folds along the lesser curvature (fig. 7). These folds, three or four in number, are very constant, and are limited to the lesser curvature. Over the rest of the stomach the folds are not so salient, and are joined together by low bridges, producing a stellate formation of variable completeness. Waldeyer attaches great importance to these folds as a help to fluids and "Flussigkeiten."

Comparison with the ruminant stomach on this point is helpful, for in the first two stomachs, where the food is destined to remain for some time the mucosa is deeply reticulated, muscle bands sometimes entering into the walls of the cells (*e.g.* camelidæ). In the psalterium (as its name implies) and the abomasus, from which the food is to make a rapid exit into the duodenum, the mucous membrane is arranged in longitudinal plicæ, so as to offer the least resistance to its outgoing, whilst at the same time increasing the glandular surface.



FIG. 8.—Superimposed tracings of twelve photographs of a single contraction phase of the human stomach. Note the great activity of the pars pylorica and greater curvature of the body of the stomach, compared with the absence of peristalsis along the lesser curvature as far as the incisura angularis. (After Kaestle, Rieder, and Rosenthal.)

Further proof of the specialisation of the lesser curvature of the pars cardiaca for some function other than that of slowly pressing the food out into the active pyloric portion may be found in the following observations:—There is a very marked difference in the action of the muscle along the lesser curvature as seen by X-rays, the change occurring at the incisura angularis. The whole diameter of the pars pylorica takes part in active peristaltic waves coursing towards the pylorus. It is, however, very rare to see any indentation of the lesser curvature in the pars cardiaca. In this portion the waves of contraction will be seen to involve the greater curva-

ture only. A reference to the well-known diagram of Kaestle, Rieder, and Rosenthal inserted as fig. 8 will make this clearer. The lesser curvature changes in position slightly, as indeed is to be expected in a viscus not rigidly fixed and subject to intrinsic muscular movements, but it does not change in shape. It would seem very probable from this alone that there is a fundamental difference in function between the lesser curvature in the two portions of the stomach, over and above the different general functions that the last are known to possess.

### CONCLUSIONS.

A review has been made of the records of this subject so far as they are available to the author, whilst his own observations have been tried in the light of the knowledge so gained. It seems fair to deduce in conclusion that there is a canal along the lesser curvature of the human stomach which conveys fluids and soft things to the pars pylorica without their mingling with the more solid food in the pars cardiaca. It was shown that the X-ray findings were such as could be reasonably explained from the arrangement of the oblique musculature and the mucous membrane of the stomach. It is reasonable to suppose that this canal is the homologue of the well-known gastric canal of ruminants, whose first two saccular stomachs are homologous with the pars cardiaca of the human stomach. The indisputable epithelial canal present in the human fetal stomach is its representative, and influences the arrangement of the oblique muscle coat, which has been shown to be capable in its turn of re-forming a canal at need. It is hoped that further confirmation or criticism may be obtained from radiographers, now that attention has been more specifically drawn to this subdivision of the stomach. It is high time that our views upon the musculature of this last underwent the same revision that our views upon the general shape and disposition of the stomach itself have undergone. For it is obviously illogical to remodel one's views on the general conformation of a viscus without at the same time recognising that the parts of which it is composed must be arranged somewhat differently from that which the old teachings had supposed. As for the actual shape of the stomach itself, fig. 2 represents to the author's mind the standard normal. But as Case remarks on this point, "I would as soon attempt to describe the normal colour of the hair, the normal colour of the eyes, the normal shape of the mouth and nose, etc." (30).

In conclusion, I have to express my indebtedness to a large number of people, but more especially to Dr Robert Knox for so kindly allowing me to use the Radiographical Department of the Cancer Hospital, Brompton, S.W., as if it were my own; to Dr Archibald Leitch for use of his labora-



tory at the same hospital; to Professor Arthur Keith for some valuable suggestions; and to my wife, Dr Gertrude Flumerfelt, for her valued help with the literature.

#### SUMMARY.

1. Lewis, and Keith and Jones, have shown that there is an epithelial passage along the lesser curvature of the human foetal stomach, such as could directly convey fluids to the pars pylorica. This is best named the *canalis gastricus*. It persists long enough to influence the arrangement of the oblique muscle fibres.

2. Many writers have brought forward evidence that such a canal persists in the human adult, and that it represents the well-known *sulcus salivalis* or *sulcus cesophagus* (*canalis gastricus*) of ruminants.

3. The writer by means of radiograms has confirmed these findings, and shows a thin fluid suspension of bismuth confined to the lesser curvature in 82 per cent. of cases examined.

4. Of the possible explanations of this fact it is shown that the most probable is that it is lying in the *canalis gastricus*.

5. The inner or oblique muscle coat of the stomach is arranged in such a manner that by its contraction it will cause a temporary cutting-off of a canal along the lesser curvature. And the mucous membrane lies in long ridges at this curvature in a manner conducive to such an action.

6. It is time that our views upon the arrangement of the musculature of the stomach were modified to suit our new views of its position, shape, and function.

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A RARE VASCULAR ANOMALY—OPENING OF THE UPPER LEFT PULMONARY VEIN INTO A PERSISTENT LEFT SUPERIOR VENA CAVA. By T. B. JOHNSTON, M.B., Ch.B., *Lecturer on Anatomy, Edinburgh University.*

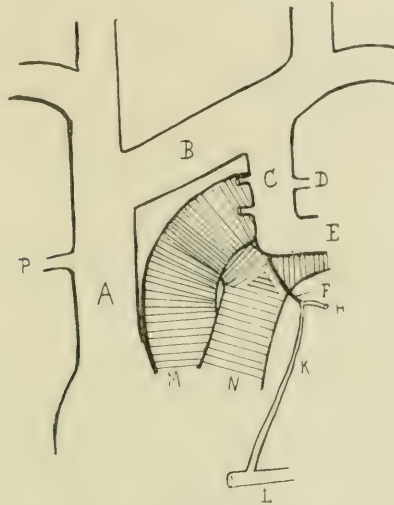
THE following vascular anomaly was found in the body of an adult male subject, dissected in the Anatomy Department of the University of Edinburgh. Unfortunately, nothing is known about the clinical history of the case, but the subject, who died from the inhalation of poisonous gases, was stated to be 56 years of age, and his muscular development was rather above the average. It may therefore be assumed that the anomaly to be described had had little effect on the health of the subject.

The condition of the great vessels of the thorax was, briefly, as follows. The superior vena cava was normal in its mode of formation, in its course, and in its termination, but its lumen was rather greater than usual. This increase in size was attributable to the left innominate vein, which, constituted in the ordinary way, received a large ascending tributary at a point about half an inch from its commencement. When this anomalous vessel was traced downwards, it was found to cross the left side of the arch of the aorta, and, in front of the left pulmonary artery, it deviated to the left in order to enter the upper and anterior part of the hilus of the left lung. In the vertical part of its course, this vein was joined, on the right side, by mediastinal and thymic tributaries, and, on the left side, by the left superior intercostal vein. At the point where it turned to the left, its lower border received the upper attachment of the ligamentum venæ cavæ sinistræ. The latter descended in front of the left pulmonary artery, and, at the lower border of that vessel, it entered the fold of pericardium with which it is normally associated. On reaching the surface of the left atrium, the ligamentum venæ cavæ sinistræ became continuous with the upper end of the oblique vein of the left atrium, which coursed downwards and to the right on the posterior aspect of the left atrium, and terminated by joining the coronary sinus. At the point where the oblique vein and the ligamentum venæ cavæ sinistræ became continuous, a small vein arose, and, after a short course, opened into the left atrium in the neighbourhood of the orifice of the lower left pulmonary vein.

The pulmonary veins of the right side showed the usual arrangement, and they opened into the left atrium by two separate orifices.

The ligamentum arteriosum was not patent, and the aorta, the pulmonary artery, and the other thoracic blood-vessels showed nothing unusual.

Certain additional anomalies were present in the heart. The organ was definitely enlarged, and this increase in size affected, more particularly, the atria and their auricles. When the interior of the right atrium was examined, the condition of the interatrial septum at once attracted attention. The floor of the fossa ovalis was unusually thin, and it showed a number of small perforations. In addition, it was definitely redundant, and



A, superior vena cava; B, left innominate vein; C, left superior vena cava; D, left superior intercostal vein; E, vein issuing from upper and anterior part of hilus of left lung; F, ligamentum venae cavae sinistae; H, small vein opening into left atrium; K, oblique vein of left atrium; L, coronary sinus; M, aorta; N, pulmonary artery; P, vena azygos.

it would appear to have bulged into the cavity of the left atrium during life. The limbus fossæ ovalis was well formed, but, in its upper and anterior part, it had failed to fuse with the floor of the fossa ovalis, and the handle of a knife could be passed upwards between the two into the left atrium. When the interatrial septum was examined from the left side, the orifice through which the instrument passed was readily seen. It possessed a sharp, slightly thickened, crescentic lower border, which was concave upwards, and in its neighbourhood numerous smaller openings occurred, giving this portion of the septum a somewhat fenestrated appearance. These openings were under cover of the limbus fossæ ovalis, which probably had a more or less perfect valve-like action, but the smaller orifices in the lower part of the septum were quite unprotected.



Another anomaly was present in the interior of the right atrium. The orifice of the superior vena cava was partially guarded by a valve, which consisted of a single semilunar cusp. The valve was situated on the anterior and right lateral aspects of the orifice. Its upper, attached, margin was convex upwards, and its lower, free, margin was straight; in its upper part the cusp showed several small perforations, similar to those often found in the valve of the inferior vena cava. The posterior extremity of its lower margin could be clearly traced down the posterior part of the right wall of the atrium, lying on the surface of the crista terminalis. Inferiorly, it became continuous with the valve of the inferior vena cava, which was also markedly fenestrated in appearance. The anterior or medial extremity of the valve of the superior vena cava could not be traced further.

Previously recorded cases of connexions between the pulmonary and the systemic veins are very few in number, and I have only been able to collect nine examples. Of these, all except two occurred on the right side; in two cases there was no opening in the interatrial septum. In none of the recorded cases is any mention made of an additional small vein opening into the left atrium; and in none was there any valve at the orifice of the superior vena cava.

The explanation of a connexion between the pulmonary and the systemic veins must depend on the view accepted for the development of the pulmonary veins. If one accepts the view, put forward by Flint (1) and others, that the pulmonary veins originate in the lungs and grow towards the heart, then it is quite clear that, under abnormal conditions, one of the pulmonary veins might meet and open into one of the systemic veins instead of into the left atrium. Such an explanation would account for the previously recorded cases, but it would leave unexplained the small vein opening into the left atrium in the present case.

On the other hand, Fedorow (2) has recently put forward the view that the pulmonary veins originate as an outgrowth from the sinus venosus and grow into the lungs. If this view is accepted, then the anomalous connexion between a pulmonary and a systemic vein is not so easy to explain.

It is known, however, that the bronchial veins, which normally terminate in the systemic veins, establish anastomoses with the pulmonary veins in the lungs. It may be suggested, therefore, that, in cases where a pulmonary vein either fails to develop or fails to reach the lung, one of these anastomosing channels becomes widely dilated, and the blood which should pass through a pulmonary vein into the left atrium passes through the anastomosis into a bronchial vein, and thus eventually reaches one of the systemic veins.

If this hypothesis is applied to the previously recorded cases, it would

appear that the pulmonary vein outgrowth from the sinus venosus had failed to break up into a sufficient number of smaller veins, *i.e.* in the previously recorded cases one of the pulmonary veins had failed to develop. In the present case the condition is slightly different. All four pulmonary veins have developed, as witnessed by the openings into the left atrium, but the upper vein of the left side, instead of reaching the left lung, met and opened into the left duct of Cuvier. It is therefore found connected with the oblique vein of the left atrium. As a result of this occurrence, the blood from the upper and anterior part of the left lung was compelled to find a new channel of return, and this was effected by the wide dilatation of an anastomosis with a bronchial vein which terminated in the left superior vena cava.

The view put forward that the small vein which opens into the left atrium and is connected to the upper end of the oblique vein is in reality the upper left pulmonary vein receives additional support from its intimate association with the ligamentum venæ cavæ sinistræ.

With reference to the anomalies in the heart itself, it is clear, since they do not occur in all the previously recorded cases, that they are not dependent on the vascular anomaly, but are simply additional signs of developmental arrest. In the upper and anterior part of the interatrial septum, the septum primum and the septum secundum have failed to fuse, and the foramen ovale secundum has persisted. The numerous smaller openings in the fossa ovalis suggest the possibility that the foramen ovale secundum may be formed by the fusion of a number of small perforations, and not in the way which is usually described.

The valve at the orifice of the superior vena cava is very similar to one described by Sir William Turner (3) in a case where the pulmonary veins and the interatrial septum were normal. It represents the persistence of the greater part of the right venous valve at the opening of the sinus venosus into the atrial chamber of the heart. It is possible that the part at the orifice of the superior vena cava may represent not only the upper extremity of the right venous valve, but also a portion of the septum spurium. This, however, is only a possibility, and no proof can be brought forward in its support.

I should like to thank Professor Robinson for granting me permission to describe this somewhat rare anomaly of the vascular system.

*Note.*—Since the above was written, I have had the opportunity of reading A. J. Brown's paper on "The Development of the Pulmonary Vein in the Domestic Cat," *Anat. Record*, vol. vii., No. 9. The conclusions at which he arrives are very similar to, although not identical with, the conclusions drawn in the present note.

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PRELIMINARY NOTE ON A DIARTHRODIAL ARTICULATION  
BETWEEN THE CLAVICLE AND THE CORACOID. By  
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THE specimen consists of the shoulder-girdle of a man æt. 50, and shows on either side a diarthrodial articulation between the clavicle and the coracoid process. The condition is not only bilateral, but for all practical purposes symmetrical. Nothing whatever could be ascertained as to the man's previous history or occupation.

The only other abnormality noted was the presence, on each side, of a well-marked sternalis muscle.

DESCRIPTION OF THE SPECIMEN.

A. *The Scapula*.—On the ventral aspect of the coracoid process, near its root, and at the site of the normal attachment of the trapezoid ligament, is an oval facet, the longest diameter of which is half an inch. This facet was covered by a firmly adherent and thick pad of fibro-cartilage.

B. *The Clavicle*.—This bone shows a clear demarcation into two parts, *i.e.*, an *inner two-thirds*, well developed, and presenting a strong anterior convexity, and an *outer third*, relatively feebly developed, giving the appearance of a secondary buttress or girder, passing to the acromion process of the scapula.

At the junction of the two parts below and behind is a well-marked projection, at the site of the conoid tubercle. This projection presents an articular facet, which is directed downwards, backwards, and outwards, and which was covered by a firmly adherent disc of fibro-cartilage.

The joint so formed between the clavicle and the coracoid was surrounded by dense ligamentous and tendinous fibres, forming a capsule, and composed in great part of the coraco-clavicular ligament. This capsule was lined by synovial membrane, which was involuted as a number of folds into the joint by small pads of fatty tissue.

The sterno-clavicular and acromio-clavicular joints were normal.



## FREQUENCY OF THE CONDITION.

The only references which I have so far been able to find are:—

1. By Testut, who mentions having seen three cases: in a woman of 40, in a negro, and in a microcephalic idiot respectively.
2. By Sir Arbuthnot Lane, who refers to the condition as being common, though no details are given.

## ETIOLOGY OF THE CONDITION.

There are, I think, two possible views. Firstly, the condition may be a congenital one. Secondly, it may be acquired; and Sir Arbuthnot Lane's view is that in individuals who habitually carry heavy weights on the head or trunk, which require the arms to keep them in position, the shoulder joints are maintained in a position of extreme flexion. The scapula is thus fixed on the clavicle by a form of locking of the coracoid and clavicle, and this is assisted by the pressure exerted by the weight carried.

Sir Arbuthnot Lane, indeed, suggests the use of this position in breaking down adhesions round the shoulder joint, and he believes that the continued apposition of the bones leads to the formation of a diarthrodial joint. He considers the condition to be an expression of the same factor which leads to the divorce of the tendon of the pectoralis minor as the coraco-humeral ligament.

As far as I am able to judge, Lane's cases were all unilateral, and the articulation was nearer to the tip of the coracoid than in the present example. He describes, however, an articulation as occurring further back in shoemakers.

It is interesting to note that a similar articulation may occur between the inner end of the clavicle and the first rib, and also that, instead of a definite diarthrodial articulation between the coracoid and clavicle, we may get deposits of cartilage in the trapezoid ligament, or in the outer portion of the subclavius muscle.

I would venture to suggest that with regard to this specimen the only rational explanation is that the condition is congenital.

This, I think, is supported by the condition being bilateral, and by its being apparently much better marked than in any case previously reported. It is somewhat difficult to imagine it as a result of weight-bearing, which would only be likely to date from or about the attainment of the adult condition.

Testut's cases, I hold, also support this view. The alteration in the

clavicle is, I think, particularly interesting, in the light of recent views as to the ossification of the bone from two primary centres, and as to its morphology from the point of view of the occurrence of cranio-cleido-dysostosis.

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MANIFESTATION OF OCCIPITAL VERTEBRÆ, AND FUSION OF  
THE ATLAS WITH THE OCCIPITAL BONE. By REGINALD  
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THE significance of variations in the occipito-atlantal and other regions of the vertebral column has within the last ten or fifteen years received a very considerable amount of attention, and it is with the view of carrying on this study one stage farther that the authors of this memoir have been drawn into this fascinating field of phylogenetic and ontogenetic research.

The two first specimens which we shall describe, "Manifestation of an Occipital Vertebra," are an example of a variation which was formerly described under the name of "pro-atlas," as it was believed that an additional vertebra was interpolated between the atlas and the occipital bone, and that this additional bone had become more or less completely incorporated with the latter. According to Kollmann, Swjetschnikow, Macalister, Elliot-Smith, and other of the more recent anatomists, however, the condition is due to a partial liberation of one of the vertebral elements which normally enter into the composition of the occipital bone, and ought not to be regarded as an additional vertebra.

I.—MANIFESTATION OF OCCIPITAL VERTEBRA.

This specimen was found in a disarticulated skull of a young subject in whom fusion of the occipital bone with the sphenoid had not yet occurred.

On the under surface of the occipital bone (fig. 1) is seen in outline what appear to be the posterior and anterior arches, the lateral masses, and the left transverse process of an atlas. On critical examination, however, it is to be noted that there is no facet for the odontoid process of the epistropheus. Moreover, the articular surfaces, which are oval in outline and converge anteriorly, are directed laterally and downward, resembling occipital condyles rather than the inferior articular surfaces on the under aspect of the lateral masses of an atlas. The articular surfaces are pitted and rough, and look as if epiphyseal cartilages had been separated by maceration. The transverse process on the right side is absent, while on the left it is well developed and separated from the jugular process of the

occipital bone, which lies in front and lateral to it. The transverse process on the left side shows no foramen for the passage of the vertebral artery. A large canal is, however, present on the left side of the foramen magnum which, when viewed from the cranial aspect, is seen to be distinct from the canal for the hypoglossal nerve (anterior condylar). On the external surface, these two canals open close together at the bottom of a depression, which may be called the anterior condylar fossa.

The canal for the hypoglossal nerve is subdivided into two by a spicula of bone. The lower large canal, which lies posterior to the hypoglossal

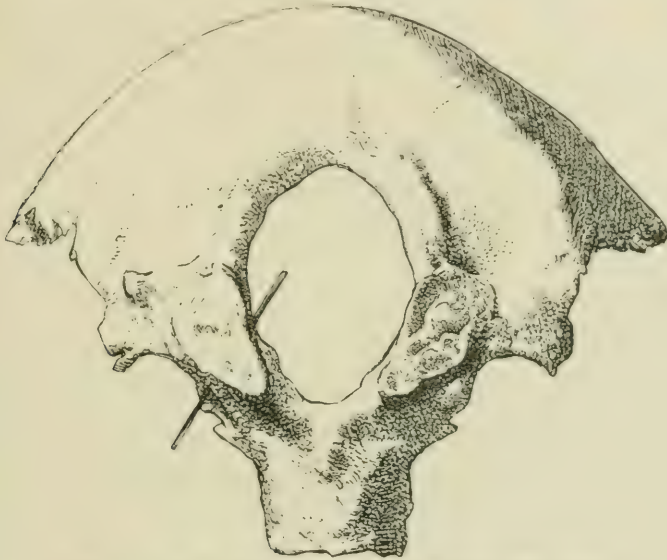


FIG. 1.—Manifestation of occipital vertebra (specimen 1).

foramen, is of sufficient size to have transmitted the vertebral artery: from its direction, however (see fig. 6), we infer that a vein passed through the foramen, and that the artery passed through the foramen magnum, after having passed between the posterior arch of the atlas and the occipital bone in the normal situation.<sup>1</sup>

<sup>1</sup> The vertebral artery, however, has been known to have passed through the anterior condylar foramen, or a large branch which will take the place of the vertebral artery may pass through the foramen; for example, a case described by N. Batuzeff (*Anat. Anz.*, May 1889) in which the basilar artery was absent, but was replaced by a vessel arising from the internal carotid artery, a short distance before this vessel entered the carotid canal. This abnormal branch entered the skull through the left anterior condylar foramen, and, having gained the basilar process of the occipital bone, gave off the usual branches of the basilar trunk; both vertebral arteries were atrophied.

In a second case described by Elliot-Smith (10), the vertebral artery passed through the anterior condylar foramen in a very remarkable and extreme case of assimilation of the



On the right side there are also two foramina. The upper on this side is the larger. It is not subdivided, and presumably both divisions of the hypoglossal nerve would have passed through the upper foramen, and the lower would have served for the transmission of a vein. As on the left side, both canals open at the bottom of an anterior condylar fossa.

On each side there is a large posterior condylar foramen, which opens on the cranial aspect of the bone into the groove for the transverse sinus.

The muscular markings and ridges on the nuchal portion of the bone are indistinct, the superior and middle nuchal lines, the external occipital crest, and the external occipital protuberance being only with difficulty distinguishable. The intra-cranial surface of the squamous portion of the bone shows marked asymmetry, the right cerebellar fossa is much smaller than the left, and the left cerebellar fossa is smaller than the right, indicating that the right cerebral and left cerebellar hemispheres were imperfectly developed.

The sagittal sinus is continuous with the right transverse sinus. This lies at a higher level and is considerably larger than the left.

atlas vertebra with the occipital. These cases may be readily explained by a reference to the early stages of development of this artery in the embryo.

Normally, a series of somatic segmental arteries are given off from the right and left dorsal aortæ. These are afterwards united in the cervical region, by a longitudinal vessel formed by intersegmental anastomoses situated between the costal elements and the transverse processes of the cervical vertebrae. The longitudinal vessel anastomoses in front with the posterior branch of the primitive cerebral artery, and forms with it a trunk called the vertebro-cerebral artery. The first somatic segmental artery, with its dorsal branch, accompanies the twelfth cranial nerve, and is known as the hypoglossal artery; the seventh persists as the first part of the subclavian and origin of the vertebral artery. The hypoglossal artery and the first six somatic arteries in the cervical region normally disappear. The longitudinal intersegmental vessel persists as the cervical portion of the vertebral artery, which is continuous below with the persistent seventh dorsal somatic artery, but has now lost its connexion through the anterior somatic arteries with that part of the dorsal aorta which forms the internal carotid artery.

Occasionally, however, the vertebral artery may arise from the internal carotid artery near the base of the skull, and, as in the case described by Batuzeff, pass through the anterior condylar foramen; or it may arise in the normal way from the subclavian artery, but instead of accompanying the first cervical nerve, pass with the hypoglossal nerve through the anterior condylar foramen. These cases are obviously due to a persistence of the hypoglossal artery.

The vertebral artery also has been known to be pierced by one of the rootlets of the hypoglossal nerve (J. W. Ogle). This is due to the persistence of the anastomosis which is normally formed between and around the fila of the hypoglossal nerve. In a human embryo of 10 mm. length, a series of segmental vessels are seen to pass from the vertebro-cerebral artery, in a dorso-lateral direction, over the side of the medulla spinalis to a longitudinal anastomosing vessel lying between the rootlets of the hypoglossal and accessory nerves. These segmental vessels pass between the rootlets of the hypoglossal nerve and between the hypoglossal and suboccipital nerves. Normally, the artery which courses ventrally between the hypoglossal and the first cervical nerves persists as the terminal portion of the vertebral artery. It represents the spinal branch of the dorsal division of a somatic segmental artery, with a preneural subdivision. This unites with a similar branch of the opposite side to form the basilar artery. In cases of complete fusion of the posterior arch of the atlas with the occipital bone, and in which there is no foramen for the vertebral artery between these bones, this vessel will have to pass either below the atlas, between it and the epistropheus, or through the occipital bone. In cases of manifestation of an occipital vertebra, the vessel usually passes between the atlas and the occipital bone. In rare instances, however, it passes through the occipital bone, either in a special canal or through the hypoglossal foramen.

## II.—MANIFESTATION OF OCCIPITAL VERTEBRA.

This specimen occurred in a Gond skull belonging to Professor David Waterston, in the Anatomical Museum at King's College.

The indications of the occipital vertebra (fig. 2) are not so complete as in the previous case. The basal portion of the posterior arch is quite



FIG. 2.—Partial liberation of occipital vertebra (specimen 2 (Gond skull)).

distinct on each side; the two halves of the arch, however, do not unite behind. Indications of transverse processes are present on both sides. On the under aspect of the right, the surface of the bone is rough, and appears as though a projection had been broken off.

The condyles and anterior margin of the foramen magnum do not differ markedly from the normal, and there is no facet for the odontoid process of the epistropheus.

A posterior condylar foramen is present on each side. The anterior condylar foramen is subdivided by a spicule of bone on both sides.

The skull in other respects appears to be quite normal, the muscular markings being well developed.

### III.—AN ATLAS VERTEBRA FUSED WITH THE OCCIPITAL BONE.

The anterior and posterior arches, and the lateral masses of the atlas, are united by bone with the under surface of the occipital (fig. 3). The transverse processes are free on both sides. On the right side the tip of the transverse process is in contact with the occipital bone, behind the jugular process, but is not fused with it. On the left side the transverse process of the atlas is separated from the occipital bone by about three

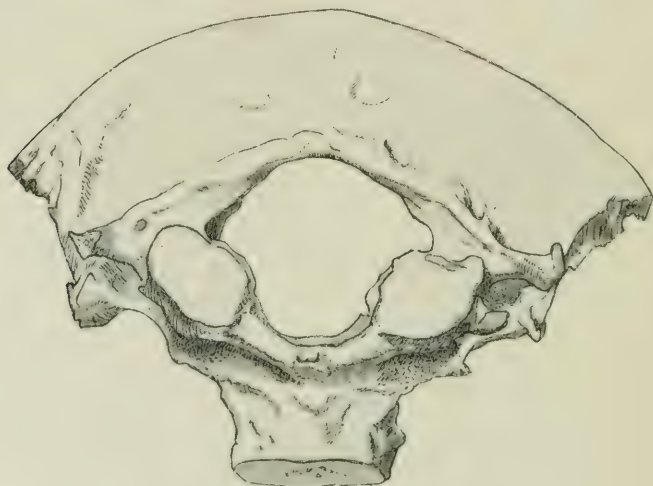


FIG. 3.—Atlas fused with occipital bone (specimen 3).

millimetres. The atlas does not differ very markedly in general appearance from the normal bone. The costal element of the transverse process is, however, rudimentary on both sides, especially the left, where it is represented by a mere spicule of bone situated in front of the groove for the vertebral artery.

At the base of the true transverse process there is on each side a small foramen, which probably served for the transmission of a vein.

A canal between the posterior arch of the atlas and the occipital bone for the vertebral artery is present on each side. On the right side a small groove is present on the posterior arch of the atlas, within this canal, for the trunk and posterior division of the suboccipital nerve.

A posterior condylar foramen is present on each side, which opens internally medial to the groove for the transverse sinus.



On both sides there is a groove for the occipital venous sinus, which on the right side is larger than that for the transverse sinus; the groove for the occipital sinus lies immediately lateral to the posterior condylar foramen, and the posterior condylar vein would thus have opened into the occipital sinus, instead of into the transverse sinus.

On the left side there is a smooth, walled, rounded hollow, formed at the bend of the transverse sinus and just below the tuberculum jugulare, which would probably have lodged a diverticulum from the transverse sinus.

On the right side there is a similar smooth, walled recess, but lateral to the groove for the transverse sinus, and separated from it by some rough bone. This is an air sinus, which is completed by articulation with the temporal bone.

The canalis hypoglossi (anterior condylar foramen) is partially subdivided on the left side; there is no indication of subdivision on the right. The bone overlying the canal is more slender than normal. There is a certain degree of asymmetry present, the left transverse process of the atlas being on a lower level than the right, and the posterior tubercle of the atlas being slightly to the left of the occipital crest. There is also a considerable downgrowth of bone on each side, lateral to the insertion of *M. rectus capitis posterior major*.

On examining the intra-cranial surface of the squamous portion of the occipital bone, it will be noticed that the groove for the transverse sinus of the left side is larger than that of the right. The groove for the sagittal or superior longitudinal sinus appears to be more directly continuous with that for the right occipital sinus than with either of the transverse sinuses.

#### IV.—COMBINATION OF FUSION OF THE ATLAS WITH MANIFESTATION OF OCCIPITAL VERTEBRA, ASSOCIATED WITH THE PRESENCE OF CERVICAL RIBS.

This is a specimen which one of us exhibited at the meeting of the Anatomical Section of the British Medical Association at Sheffield in 1908.

The specimen occurred in a female subject aged 86 which was dissected at the Middlesex Hospital.

Round the margin of the foramen magnum are indications of lateral masses, anterior and posterior arches, and the transverse processes of an occipital vertebra.

The anterior arch bears a facet directed downwards and backwards for the tip of the odontoid process of the epistropheus.

The transverse processes present no foramen for the vertebral artery and are directed downwards and laterally. The right bears a facet on its under surface for articulation with the transverse process of the atlas. The left is fused with the corresponding transverse process of the atlas.



The anterior condylar foramen is subdivided on the right side, and single on the left.

Below the basilar process of the occipital bone there is a distinct groove, seen on both the intra- and extra-cranial aspects, marking off the anterior arch of the occipital vertebra from the occipital bone.

There is also a small tubercle on the anterior arch of the occipital vertebra, presumably for the attachment of *M. longus capitis*.

The atlas has the normal appearance of the first cervical vertebra, but differs in the following respects: the anterior arch is slightly hollowed out for the reception of the odontoid process, but there is no distinct facet.

The bone is fused with the occipital vertebra by the left transverse

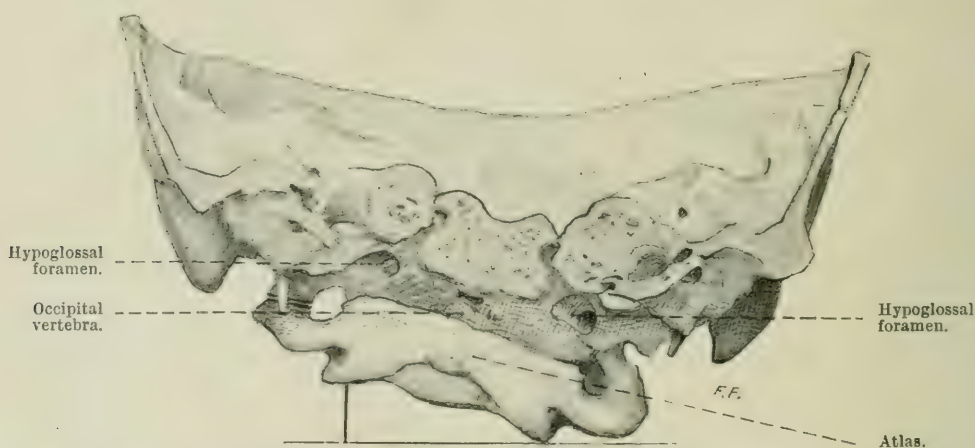


FIG. 4.—Specimen in which the atlas is fused with a partially liberated occipital vertebra. In the same subject a cervical rib was present on each side.

process and superior articular facet of the lateral mass. The right transverse process and superior articular process are in contact, but not fused with the occipital vertebra, a cleft-like space intervening between the paracondylar or transverse process of the occipital vertebra and the transverse process of the atlas, and also between the right condyle of the occipital vertebra and the superior articular facet of the atlas. The anterior and posterior arches are free.

The atlas is placed very obliquely, with relation to the base of the skull, and, like the specimen previously described, the left transverse process is considerably lower than the right. The transverse process on both sides is enlarged in an upward and backward direction to meet the transverse process of the occipital vertebra.

In the same subject a rudimentary cervical rib was present on each

side, which will be described in a separate paper, and a persistent foramen of Huschke was present in each tympanic plate.

In contrasting these two varieties, the points which we would lay most stress upon are the following :—

#### Manifestation of Occipital Vertebra.

Condyles oval in outline ; convex ; converge anteriorly ; surfaces directed downwards and laterally ; slight constriction separating anterior from posterior part of condyle. The condyles encroach only slightly, or not at all, on the foramen magnum.

The anterior arch usually has no facet for the “dens epistropheus.” In rare cases, however, a third occipital condyle may be developed on an “arcus præbasii-occipitalis” (“Manifestation des Occipital Wirbels,” Schumacher, *Anat. Anz.*, Bd. xxxi. S. 153 ; and fig. 5, specimen 6221, Museum of Royal College of Surgeons, England).

The anterior arch is usually completely fused with the occipital bone.

Posterior arch not so wide as that of the atlas, and less distinctly marked off from the occipital bone. Usually no gap between it and the occipital. No canal for vertebral artery and suboccipital nerve between the posterior arch and the occipital bone. A groove is sometimes present on the under surface of the bone for the vertebral artery, immediately behind the condyles.

Transverse process as a rule presents no foramen for the vertebral artery, and is less separated from the occipital bone.

#### Fusion of Atlas with Occipital.

Inferior articular facets nearly circular in outline ; slightly concave ; directed downwards and medially. The lateral masses encroach considerably on the foramen magnum. Cases, however, in which the atlas has fused with the occipital bone sometimes show a rounding off of the inferior articular facets, so that they may resemble the condyles of the occipital bone. This is due to the movements of flexion and extension of the head being transferred from the occipito-atlantal articulation to the joints between the atlas and the axis.

The anterior arch usually has a facet for the odontoid process of the axis (dens epistropheus). There is usually an anterior tubercle for the attachment of the *M. longus capitis*. The anterior arch is frequently separated by a gap from the anterior margin of the foramen magnum.

Posterior arch wider, forming an arc of a circle, the centre of which would be near the pharyngeal tubercle.

The posterior arch is separated from the occipital bone by a canal for the vertebral artery and suboccipital nerve, or there is a distinct gap between the posterior arch and the occipital bone, with a groove on the former, as in the normal bone.

Transverse process frequently free, and pierced by canal for vertebral artery. Costal element may, however, be rudimentary, in which case a groove for the artery may usually be recognised in front of the true transverse process ; it may be united or articulate with the occipital bone by means of a paroccipital process.

Although the distinguishing points we have given above are usually sufficient to distinguish manifestation of occipital vertebra from fusion of atlas, exceptions sometimes occur which render the distinction difficult.

Thus, in a specimen described by J. Kollmann as “manifestation of an

occipital vertebra," a third or median condyle was present on an arch at the anterior margin of the foramen magnum, and a well-marked anterior tubercle was also present.

Another anomalous case is described by the late D. J. Cunningham as "manifestation of an occipital vertebra." This was considered by Professor Kollmann to be a high degree of assimilation of the atlas with the occipital bone. In this specimen there was no facet on the anterior arch, the articular facets on the under surface of the bone were convex, and there was no large foramen in the transverse process.

Farther, there was no canal between the posterior arch and the occipital bone for the vertebral artery and suboccipital nerve.

Notwithstanding these important points in favour of "manifestation of occipital vertebra," Professor Kollmann considers that Cunningham was mistaken in supposing this specimen was an example of manifestation of occipital vertebra, basing his opinion chiefly on the shape of the inferior articular facets. Professor Elliot-Smith, at a meeting of the Anatomical Section of the British Medical Association in July 1908, in commenting upon Kollmann's article, was disposed to agree with Professor Cunningham, but cites a case of his own in which the vertebral artery of the right side passed upwards in front of the transverse process to an anterior condylar fossa, and from thence turned medially through the occipital bone so as to open on the side of the foramen magnum below the *canalis hypoglossi*. Moreover, there was a facet on the anterior arch for the odontoid process of the axis, and, judging from the figure, this was directed downwards, and would have been supplementary to the facet on the anterior arch of the true atlas or first cervical vertebra.

Thus, a facet on the anterior margin of the foramen magnum, although in favour of fusion of the atlas with the occipital bone, may be present in a genuine case of manifestation of an occipital vertebra, as in cases previously mentioned, described by Schumacher (20), and specimen 621.1, Museum of Royal College of Surgeons, England (fig. 5). The odontoid process of the epistropheus would therefore in these cases have presented two facets, one at its tip for the third occipital condyle, and one on its anterior surface for the arch of the atlas. With regard to the foramen on the left side of the foramen magnum in the specimen that we have described (fig. 1 and fig. 6, B), it is difficult to say whether it would have transmitted the vertebral artery or the vein which usually accompanies the hypoglossal nerve.

A shallow groove within the foramen magnum, leading up to the canal from behind, appears to be in favour of the vessel being a vein, more especially as a similar groove leads up to the lower of the two foramina on the right side.



Farther, the direction of the canal from the intra-cranial aspect of the foramen magnum is forwards and laterally (fig. 6, B), whereas in a canal which would have transmitted the vertebral artery, the direction from the extra-cranial aspect would be medial, and then forward in a curved direction to the basilar process of the occipital bone (fig. 6, A). Moreover, the canal for the vertebral artery lies behind the superior articular process of the atlas.

The composite nature of the occipital bone is indicated by a study of

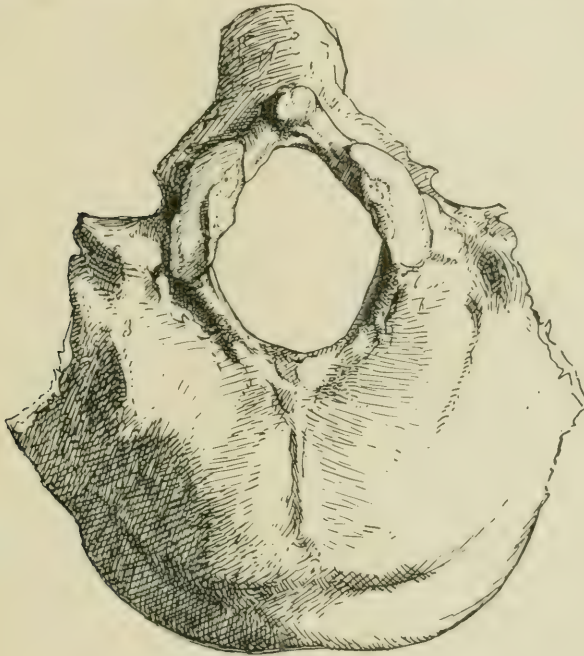


FIG. 5. —Manifestation of occipital vertebra.

the hypoglossal nerve, and the cranio-vertebral skeleton of the lower vertebrates, and especially in the dipnoi and certain fishes.

The hypoglossal nerve is generally believed to represent one or more of the anterior spinal nerves, and its transformation into a cerebral nerve can be traced in passing through the vertebrate series. The hypoglossal nerve "in some fishes and in all amphibia does not pass through the cranial wall, and is a true spinal nerve. In most fishes, and in the dipnoi, its inclusion within the skull can be seen to be due to a gradual assimilation of the anterior part of the vertebral column with the skull. In protopterus the hypoglossal nerve has two dorsal roots, each provided



with a ganglion" (*Comp. Anat. of Vertebrates*, Wiedersheim and Parker, p. 188).

Moreover, an examination of the basis cranii and rootlets of the hypoglossal nerve in young embryos gives further indications of the composite character of the occipital bone. In human embryos, for example, between 6 and 10 mm. length (see fig. 7) the rootlets of the hypoglossal nerve may be seen passing downwards from the medulla spinalis through what appears to be unsegmented mesenchyme. They are arranged in four or five groups, which converge to form two main trunks before finally joining in a single trunk. Medial to them are seen minute arteries, which are arranged in



FIG. 6. A.—Assimilation of atlas with occipital bone (specimen 3), showing the curve and direction of the canal for the vertebral artery. B.—Manifestation of occipital vertebra (specimen 1), showing the direction of the canal below the anterior condylar foramen which presumably transmitted a vein.

series corresponding to the rootlets of the hypoglossal nerve. These vessels are probably intersegmental in nature, and pass between the vertebro-cerebral artery and a longitudinal trunk lying lateral to the rootlets of the hypoglossal nerve; like the rootlets of the hypoglossal, they are four or five in number on each side. They correspond to the intervals between the rootlets of the hypoglossal nerve, and between the latter and the suboccipital nerve; in the specimen figured they are five in number.

Froriep (11) believes that the occipital region in the human subject is formed by the fusion of four rudimentary vertebrae, corresponding to three primary roots of the hypoglossal nerve. Of these four, only the posterior is at all independent; its development in the early stages resembles that of the vertebrae, and loses its identity only when fused with the parts in front of it (*Quain's Anatomy*, vol. i.: *Embryology*, T. H. Bryce, p. 255 (4)).

The partial independence of the last occipital vertebra has also been demonstrated by Weiss (23) in the white rat, who not only proves the existence of posterior and anterior arches of a last occipital vertebra, but also the presence of an independent mass of dense mesodermal tissue, forming the anterior part of the odontoid process of the epistropheus.

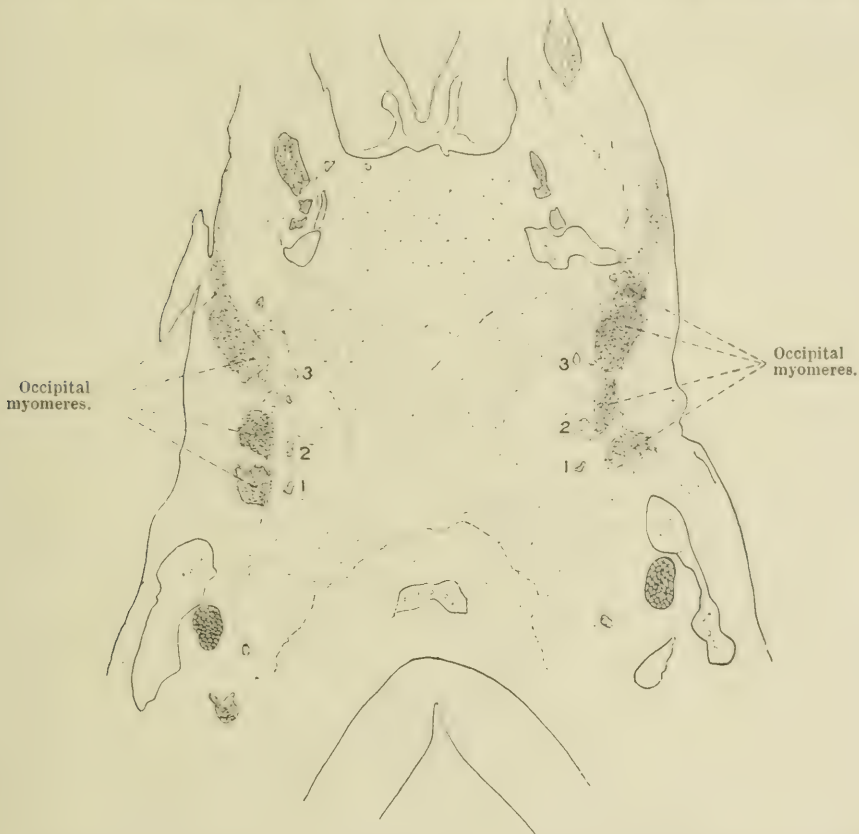


FIG. 7. —Transverse section of a human embryo (6 mm.), showing four occipital myomeres medial to which are the rootlets of the hypoglossal nerve. (From a specimen belonging to Professor D. Waterston.)

The odontoid process consists, therefore, in the white rat, of a basal portion, corresponding to the body of the atlas, and an apical portion which represents the body of a pro-atlas or last occipital vertebra.

In the human subject the relation of the transverse ligament of the atlas and the alar occipito-odontoid ligaments (check) to the base and tip of the odontoid process are confirmatory with regard to this view.

The serial homology of these ligaments was pointed out many years ago by J. Bland-Sutton (3) in his treatise on the Nature and Morphology of Ligaments, where he describes the transverse and check ligaments as being "repetitions of the posterior conjugal ligament" which connects the heads of the ribs behind the intervertebral discs in the thoracic region.

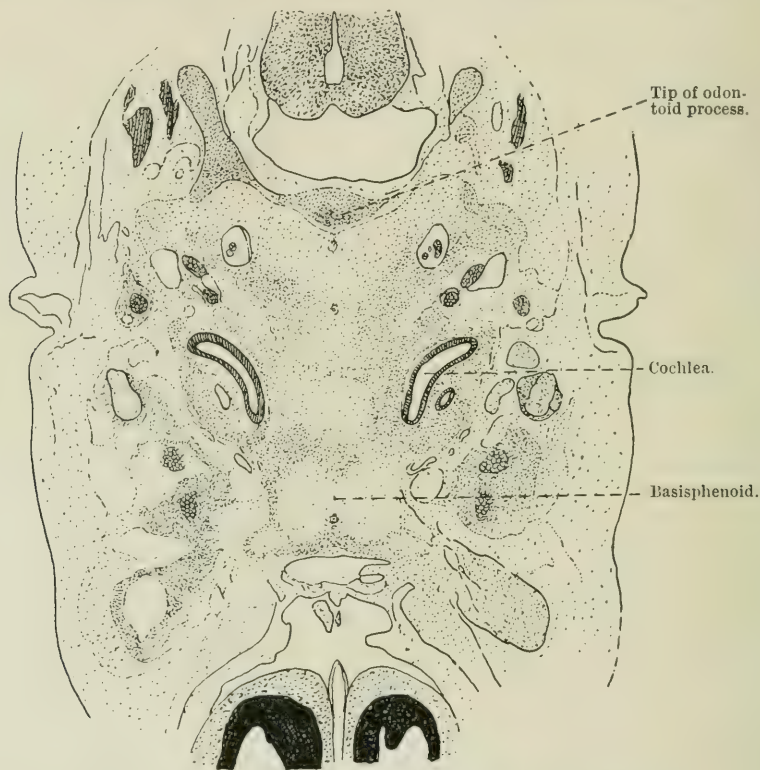


FIG. 8.—Horizontal section through the base of the chondro-cranium of a human embryo (22 mm.), showing swellings of the notochord at the tip of the odontoid process, and in the occipital region of the basiscranial axis. The light areas represent areas of chondrification; these are separated by more deeply stained bands which lie between the cartilaginous centre in the position of intervertebral discs. (From a specimen belonging to Professor D. Waterston.)

Our observations on human embryos confirm Froriep's and Weiss's views with regard to the composite nature of the occipital bone in lower vertebrates. Fig. 7, which is a drawing from a transverse section of a 6 mm. human embryo belonging to Professor D. Waterston, shows indications of four occipital myomeres with intersegmental vessels, and three main groups of the rootlets of the hypoglossal nerve. These

latter separate four more deeply stained areas which correspond to occipital scleromeres.

At a later stage, as seen in fig. 8, drawn from a transverse section of a 22 mm human embryo, also the property of Professor D. Waterston, it will be noticed that in the occipito-sphenoid plate there are four lightly stained areas of chondrification. The anterior of these represents the basisphenoid, and the termination of the notochord is seen within it. Behind this, in the occipital portion of the plate, three areas of chondrification, separated by two darkly stained bands, are visible. One of these bands lies at the level of the first turn of the cochlea. The next shows in its centre a swelling of

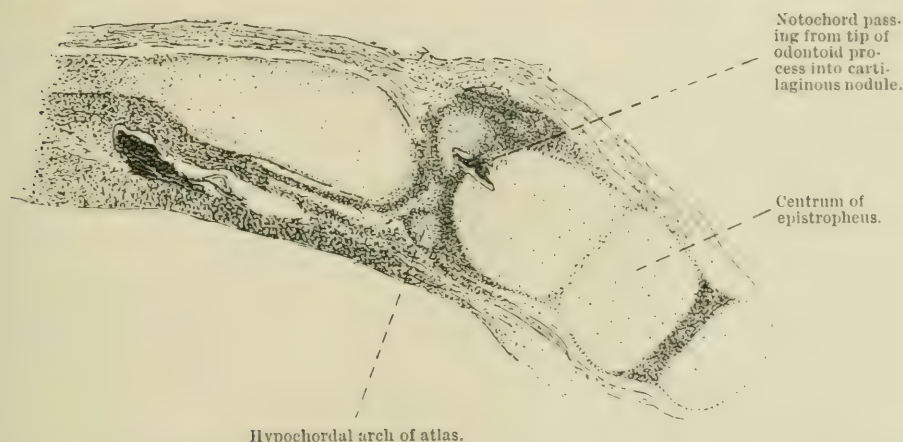


FIG. 9.—Longitudinal section of a 16 mm. human embryo, showing the notochord passing from the tip of the odontoid process into a cartilaginous nodule representing the centrum of a last occipital vertebra or pro-atlas. Ventrally to this is seen a section through the hypochordal arch of the atlas.

the notochord. A second swelling of the notochord is seen at the anterior margin of the foramen magnum. The occipital plate therefore appears to be formed from three centres of chondrification, which afterwards fuse with one another, and with the basisphenoid, to form the continuous occipito-sphenoid cartilage seen in later stages.

The cartilaginous centre of the body of a last occipital vertebra, or pro-atlas, is sometimes developed in the human embryo, as is seen in fig. 9 and fig. 10. It is situated in front of the odontoid process of the epistropheus, and is traversed by the notochord. Fig. 9 is a drawing of a sagittal longitudinal section through the occipito-cervical region of a 16 mm. human embryo, belonging to Professor Waterston, and fig. 10 is an idealised mesial section reconstructed from this and neighbouring sections of the same series.



A slight constriction and a zone of closely packed nuclei show the line of demarcation between the body of the epistropheus and the dens. The hypochordal arch of the atlas vertebra is seen in the angular interval between the dens and occipital cartilage. There is in this specimen no clear indication of a hypochordal arch of the last occipital vertebra.

On examining other human embryos cut in longitudinal and transverse serial sections, we were unable to find another cartilaginous centrum so distinctly differentiated from the body of the atlas as the one figured above; nor have we found one in the embryos of lower mammals which we have ex-

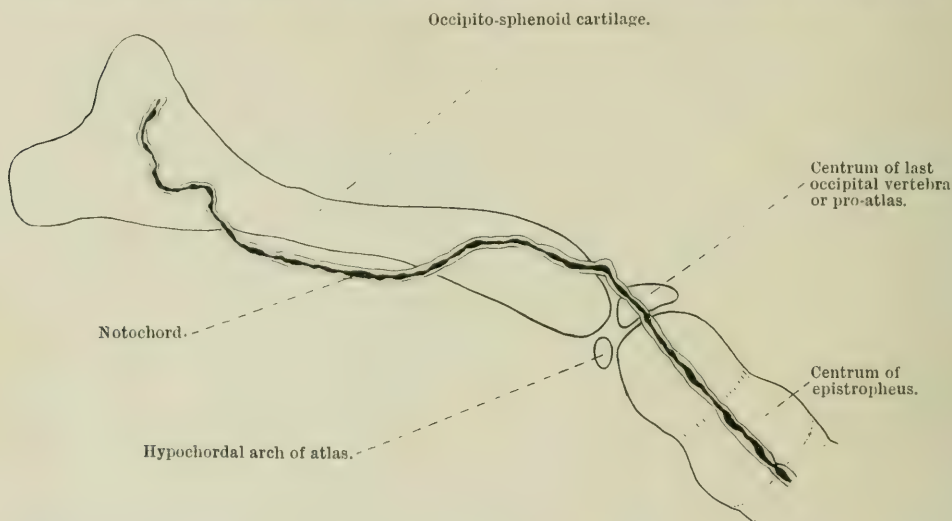


FIG. 10.—An idealised medial section, reconstructed from the section shown in fig. 9 and neighbouring sections of the same embryo, showing the relations of the notochord to the epistropheus, the centrum of the last occipital vertebra or pro-atlas, and the occipito-sphenoid cartilage.

amined, viz., carnivores (dog, cat) and rodents (mouse, guinea-pig, rabbit). Weiss, as we have previously mentioned, has, however, demonstrated in the white rat that the body of a post-occipital vertebra fuses with the body of the atlas, and forms the point of the dens epistropheus. On the question whether this rudiment should be regarded as the body of a true occipital vertebra, or as a pro-atlas, he does not, however, express a definite opinion.

If a median sagittal section be made through an axis vertebra, it will be noted that the height of the dens and body taken together is greater than the bodies of two cervical vertebræ and an intervertebral fibrocartilage. It is in fact nearly equal in height to the bodies of three cervical vertebræ. There is also in young bones a lenticular disc of cartilage between the body of the epistropheus and the dens. This disc

is situated near the junction of the lower third with the upper two-thirds of the bone. Moreover, the apical portion of the bone which gives attachment to the alar or lateral occipito-odontoid ligaments is denser in structure than the lower cancellous portion of the bone, and is sometimes marked off from the body of the atlas by a thin plate of compact bone. It appears to us, therefore, that the dens is formed from two centra, in addition to the centrum of the epistrophæus: a lower, the body of the atlas; an upper, the body of a pro-atlas or last occipital vertebra. In exceptional cases the latter is represented in the embryo by a separate centre of chondrification. Normally, however, a single cartilaginous centre represents the two elements. The main portion of the dens, including a part of the apex, is ossified from the two primary ossific centres. The extreme tip of the odontoid process is, however, ossified by a separate centre, which appears about the third year. This is considerably earlier than the date of appearance of the secondary or epiphyseal centres of the bodies of the vertebrae, which is stated to be about the sixteenth year. It appears to us, therefore, that this apical ossific centre may represent the primary centre of the body of a pro-atlas or last occipital vertebra, and that it is not, as usually supposed, epiphyseal in nature.

*Significance of Serial Variations of the Occipito-cervical Region  
of the Vertebral Column.*

The specimens which we have described are of considerable interest with regard to the light which they may throw upon the nature of serial variations of the vertebral column in general. Attempts have been made in the past to explain these variations upon a phylogenetic basis. For instance, it has been considered by certain authors that the occurrence of pronounced variations in individuals indicates the line along which progressive or regressive changes of the vertebral column are gradually taking place in the evolution of the race. Others have regarded these variations as having no general significance, and believe that they are due to some accidental or local cause, such as intrauterine pressure, or disease. Certain cases obviously do fall into this category, and we shall allude to them later.

The bearing that the cases which we have described has upon the main theories which have been advanced, we shall discuss under the following headings.

*Tendency towards Lengthening of the Vertebral Column.*

The appearance of an additional vertebra in front of the atlas was formerly regarded as an addition to the total number of elements in the vertebral column, and, as we have previously mentioned, was for this reason

called a pro-atlas. Farther, the occasional occurrence of such a vertebra in individuals was regarded as indicating a general tendency towards lengthening of the vertebral column. From what we have stated before, however, this tendency, if present, should not be regarded as a lengthening due to the addition of a new vertebral element, but rather as taking place at the expense of the cranium; or, in other words, by liberation of an occipital vertebra. Now, as the occipital bone of the higher vertebrates has been formed (*vide ante*) by the inclusion in the cranium of vertebrae which were originally separate in the lower vertebrates, the liberation of an occipital vertebra would be regarded by most zoologists as a reversionary or regressive variation.

*Tendency towards Shortening of the Vertebral Column.*

Fusion of the first cervical vertebra with the occipital bone, on the other hand, has been regarded as indicating a general tendency towards shortening of the vertebral column. If both these theories are correct, we have an indication of variation in two opposite directions, viz., shortening and lengthening of the vertebral column.

*Variation about a Mean, with Compensatory Changes in Other Regions.*

To harmonise this discrepancy, Dwight, Elliot-Smith, and others have advanced the theory that these variations do not indicate any progressive or regressive change in the direction of shortening or lengthening of the column, but are the expression of variations in these two directions occurring about a mean, and that they are frequently accompanied by compensatory changes in other regions. In other words, the occasional pronounced variations which are described as abnormal are merely exaggerations of slight individual variations which are normally present. The tendency to variation in one region is frequently accompanied by variations in other regions of the body. This appears in some cases to be compensatory, but not in all, as the variations may be of quite a different character, and not serial in type; *e.g.*, in specimen 4 (fig. 4), manifestation of an occipital vertebra is associated with fusion of the atlas, with cervical ribs, and a persistent foramen of Huschke which was present in each tympanic plate. The presence of cervical ribs in this specimen can hardly be regarded as indicating a lengthening of the vertebral column, as, although the thoracic region has been lengthened by one segment, this is at the expense of the cervical region, which is therefore shortened. Possibly the partial liberation of an occipital vertebra in this skeleton might be regarded as a compensatory lengthening



of the cervical region. The fusion of the atlas, however, would appear to negative this view, for the cervical region is diminished in length in both directions, by the assimilation of the atlas with the occipital bone at one end, and the development of cervical ribs at the other.

#### *Arrest of Development.*

Arrest of development has been thought to account for some cases of manifestation of an occipital vertebra. The last occipital vertebra is said to be more distinctly marked off from the preceding vertebral elements in the young embryo than it is in older embryos and in the adult, and it is believed that the normal fusion of the last occipital vertebra with the rest of the bone has been prevented. Those cases, however, in which a distinct anterior arch, with a facet for the dens epistropheus upon it (fig. 5), and in which other parts of an occipital vertebra are clearly visible, appear to us to be an advance rather than an arrest of development. Manifestation of occipital vertebrae is, moreover, sometimes associated with the development of additional tendons of insertion for the *M. longissimus cervicis*, and the *M. splenius cervicis*. These additional slips are attached to a paracondylar process of the occipital bone (A. W. Verhoef, 21), and their formation can in no sense be regarded as an arrest of development.

In cases of fusion of the atlas with the occipital bone, it is certainly true that the separation of the atlas from the occipital bone by the formation of arthrodial joints is secondary; and that the cartilages of the atlas and occipital bone are primarily united by a continuous tissue, characterised by its staining properties and the large number of closely set nuclei. In cases of fusion of the atlas, this tissue does not break down to form a diarthrodial joint, and in this sense there is an arrest of the normal development of the arthrodial joints between the atlas and condyles of the occipital bone. Arrest of the normal development of these joints does not, however, account for the marked variations in the shape and degree of development of the atlas which are frequently met with in cases of its fusion with the occipital bone, or in which there are other congenital variations in the same subject of a different nature, such as the development of cervical ribs.

#### *Intrauterine Pressure.*

It is possible that this may account for some cases. For instance, in specimen 3 (fig. 3)—fusion of the atlas with the occipital bone—on looking at the intracranial aspect of the bone, the region around the foramen magnum appears to be pressed up into the posterior cranial fossa.

Pressure would, however, hardly account for the fusion of the atlas



with the occipital in specimen 4, in which manifestation of an occipital vertebra and cervical ribs were also present in the same subject; for if we regard the fusion of the atlas, the manifestation of the occipital vertebra, and the development of cervical ribs as being associated variations produced by the same cause, we would have to regard the liberation of the occipital vertebra, and the development of cervical ribs, as due to intrauterine pressure, if this was the real cause of fusion of the atlas with the occipital.

### *Pathological Cases.*

A few cases of fusion of the atlas with the occipital bone are undoubtedly due to disease occurring either in utero or after birth. They can usually be distinguished by signs of inflammation, which affect not only the bones immediately concerned but also neighbouring parts. These cases come into another category, and are outside the scope of this paper. We may, however, mention that fusion of the atlas with the occipital bone may, as pointed out by Dwight, favour dislocation of the atlas from the epistropheus, and that if in such a case the individual had survived the injury it might be thought that the fusion of the atlas with the occipital bone was secondary to inflammation set up by the dislocation.

From among the different and often conflicting theories mentioned above to account for congenital variations in the occipito-atlantal region, it is difficult to decide on any one as being the cause in particular cases.

These theories may be summarised as follows:—

- (1) Tendency to shortening of the vertebral column.
- (2) Tendency to lengthening of the vertebral column.
- (3) Variation about a mean, with compensatory changes in other regions.
- (4) Arrest of development.
- (5) Intrauterine pressure.
- (6) Prenatal disease.

Speaking generally, variation about a mean, with compensatory changes in other regions of the body, may be regarded as an established biological principle, which governs or acts on this region as well as on growth and development in general. We would be inclined, therefore, to regard the majority of these variations in the occipito-atlantal region as largely attributable to this cause; and, further, that their occurrence does not point to any special tendency in the direction of either evolution or regression.

In conclusion, we wish to express our thanks to Professor Waterston for kind assistance, and for the use of his valuable serial sections of human embryos; also to Professor Arthur Keith for permission to draw the

specimen fig. 5, showing the hypochordal arch of a last occipital vertebra, in the Museum of the Royal College of Surgeons, England: and, finally, to Mr Walpole Champneys for the skilful manner in which he has executed the drawings.

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THE CRANIAL ATTACHMENT OF THE INTERNAL LATERAL  
LIGAMENT OF THE LOWER JAW: WITH AN INVESTI-  
GATION INTO THE FIBROGENESIS OF THIS STRUC-  
TURE. By JOHN CAMERON, M.D., D.Sc., *Lecturer on Anatomy,*  
*Middlesex Hospital Medical School.*

I.—THE CRANIAL ATTACHMENT OF THE INTERNAL LATERAL LIGAMENT.

THE internal lateral ligament of the lower jaw has been a mystery to the writer for many years. It is generally regarded as the remains of part of the perichondrium of Meckel's cartilage, but if one considers for a moment how very tiny the latter structure is, one is forced to the conclusion that its connective tissue sheath would give rise merely to the minutest of bands. This has been a difficulty to the writer for a considerable period of time, so that one has felt that there must be other sources for what is frequently a very well-defined and convincing ligamentous structure.

The main purpose of this paper is, first of all, to attempt to clear up a widespread misconception which exists regarding the cranial attachment of this ligament, and in that way obtain a clue to its identity. Thus, in all the text-books which the writer has had access to, the upper end of the ligament is invariably stated to be affixed to the spine of the sphenoid. A close inspection of the course of the ligament, however, will clearly show that, as a matter of fact, it enters the inner extremity of the Glaserian fissure, and, whilst doing so, is merely attached to the spine of the sphenoid *by its inner edge*. The writer would therefore like to suggest that this attachment to the sphenoidal spine simply exists because the latter structure happens to be situated exactly at the inner end of the Glaserian fissure, and is thus purely adventitious, the true morphological attachment being in reality to the lips of the fissure, and also within the tympanic cavity itself, as will be shown presently (fig. 1).

If, now, the attachment of the ligament to the fissure be closely investigated, it will be found that a considerable proportion of the fibres passes right through into the tympanum, and becomes directly continuous with the fibrous layer of the membrana tympani. An interesting and significant fact is that the processus gracilis of the malleus is imbedded in the midst of this fibrous tissue. This intratympanic portion of the internal lateral ligament will be found to be the structure described in text-books as

the anterior ligament of the malleus (*Quain's Anatomy*, 10th edition, vol. iii. part iii. p. 92). This band was for long regarded as containing a bundle of muscle fibres, to which the term *laxator tympani* was given. In more recent years the existence of these muscle fibres has been questioned. The writer has personally been unable to detect any indications of the presence of this muscle bundle in sections of embryos. Recently Chaîne<sup>1</sup> revived this idea in reference to the spheno-mandibular ligament.

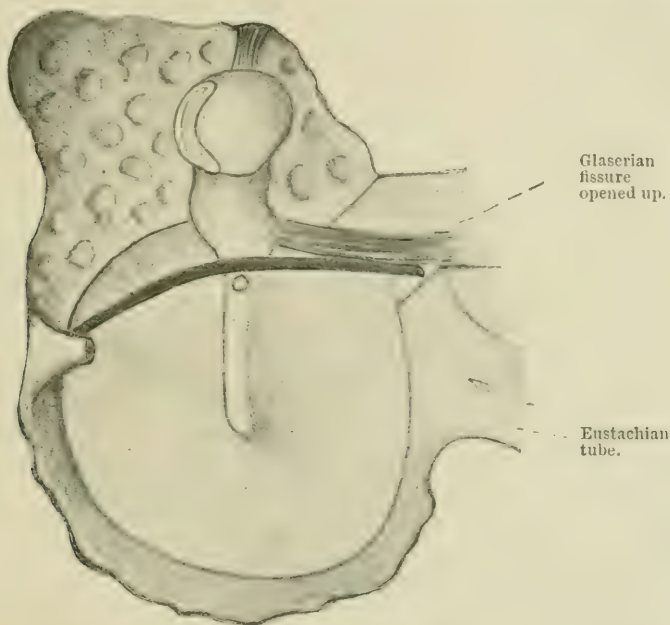


FIG. 1.—A drawing of the inner aspect of the left membrana tympani, showing the continuity of the internal lateral ligament of the jaw, with the anterior ligament of the malleus. Magnified five times.

by describing it as transformed muscle. This point will be referred to again presently.

The chorda-tympani nerve bears a most intimate relationship to the intratympanic portion of the internal lateral ligament, for it is in immediate contact throughout, or practically imbedded in its substance (fig. 1). The association of the nerve to the ligament in the Glaserian fissure is just as intimate, the two in their passage through still maintaining the above close relationship to one another. Therefore the so-called canal of Huguier is not a minute rounded channel for the passage of the nerve,

<sup>1</sup> *Comptes rendus, Biologie*, 1903.



but is in reality represented usually by a rather ragged chink, designed for the passage of both the nerve and the ligament.

## II.—THE FIBROGENESIS OF THE SPHENO-MANDIBULAR LIGAMENT.

As this preliminary investigation of the cranial attachment of the ligament proved so interesting, the writer decided to study its embryology. It forms quite a prominent band in the seventh month foetus, and passes in the most definite manner upwards into the tympanum through the gap

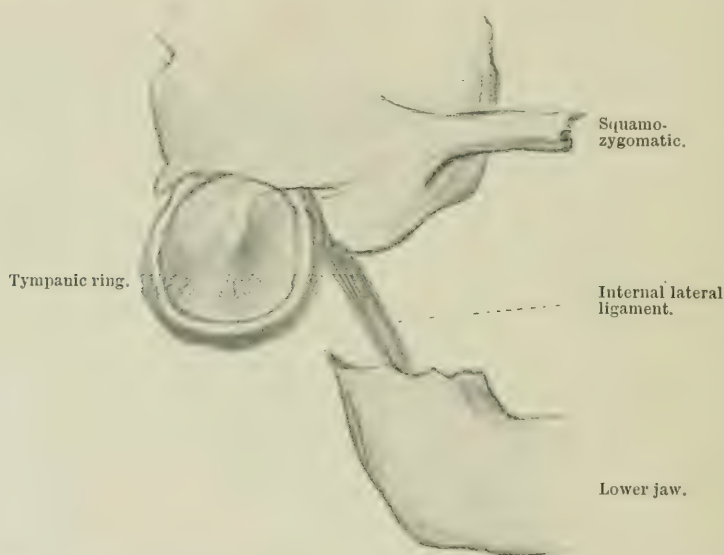


FIG. 2 shows the passage upwards of the internal lateral ligament into the tympanum between the tympanic ring and the squamo-zygomatic element of the temporal bone. It appears to be independent of the sphenoid bone altogether. Magnified about two times. Seventh month foetus.

between the tympanic ring and the squamo-zygomatic element of the temporal bone (fig. 2). This gap of course becomes the Glaserian fissure after the tympanic ring is transformed into the tympanic plate. In the foetal tympanum the fibres blend with the fibrous layer of the membrana tympani. A study of the ligament in the foetus thus absolutely confirmed the impression of its cranial attachment in the adult. It certainly passes between the two elements of the temporal bone in the most decided manner, and very definitely separates them : and appears, moreover, to be independent of the sphenoid bone at this stage.

On investigating the possible mode of origin of the ligament, the writer was much struck with the presence of a dense mass of mesenchyme surrounding Meckel's cartilage at the point where it is continuous with the malleus in a 32 mm. human embryo.<sup>1</sup> Fig. 3 is drawn from a section on slide 60 of the series, which shows Meckel's cartilage (*m.c.*) apparently



FIG. 3 (from a 32 mm. human embryo) shows a dense mass of mesenchyme lying between the malleus (*ma.*) and Meckel's cartilage (*m.c.*), thus occupying the position of the future "spheno-mandibular" ligament (slide 60). The malleus and Meckel's cartilage were in direct cartilaginous continuity in slide 59. (From a specimen kindly lent by Dr R. J. Gladstone.)

*In.*, incus; *ch.ty.*, chorda tympani; *Ex.a.m.*, ext. aud. meatus; *p.*, pinna; *E.t.*, Eustachian tube; *i.d.n.*, inferior dental nerve; *Ph.*, pharynx; *l.j.*, ossifying lower jaw.

separate from the malleus (*ma.*), the interval being filled up with a compact mass of mesenchyme. The malleus and Meckel's cartilage were, however, shown to be directly continuous in the sections on slide 59. These two structures, in fact, appear to be in direct continuity with one another, up

<sup>1</sup> The writer wishes to express his cordial thanks to Dr R. J. Gladstone for the free use of the serial sections of this embryo.

to the 100 mm. stage at least, for Professor E. Fawcett informs me that this is so in the 100 mm. embryo of his series. Low's 95 mm. embryo<sup>1</sup> shows this also, whilst the reconstructed model of the skull of an 80 mm. embryo figured in Hertwig's *Entwickelungslehre* (fig. 368) demonstrates this fact very clearly too. Also should be mentioned Kölliker's well-known figure showing Meckel's cartilage continuous with the malleus in an eighteenth week human foetus (which would certainly represent a length of over 100 mm.). At any rate there can be no doubt that between the fifth and seventh months "absorption" of Meckel's cartilage occurs; for by the end of the latter month it has practically entirely disappeared. How has this occurred? So far as I can ascertain, this portion of the cartilage

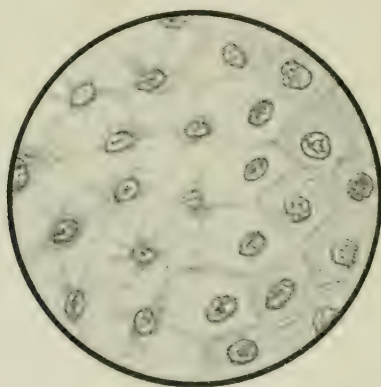


FIG. 4 shows the retrogression of Meckel's cartilage (on the right) into mesenchyme syncytium  $\times 400$ . Sixth month foetus.

reverts to its primitive mesenchymatous condition, and this mesenchyme in its turn becomes retransformed into the connective tissue of the internal lateral ligament. This reversion of cartilage back to its early embryonic state is a well-recognised fact, and has been recently emphasised in the case of the developing ribs by Geddes.<sup>2</sup>

There can therefore be no doubt of the fact that the cartilage of Meckel becomes "absorbed," but it is difficult to furnish absolutely authentic proof of the actual process at any given stage. This is not surprising, seeing that the absorption must be spread over a considerable period of time. There are, however, several very suggestive facts which prove that this is actually taking place. First of all, the perichondrium outline becomes indistinct and appears to merge with the surrounding mesenchyme. In

<sup>1</sup> *Journ. of Anat.*, vol. xlv.

<sup>2</sup> *Journ. of Anat. and Phys.*, vol. xlvii. p. 18.

the second place, it will be found that the cell-capsules on the surface of the cartilage become opened into, thus exposing the nuclei with their investing endoplasm, while the capsule-walls, which of course represent the ectoplasm of the cartilage, become directly continuous with the mesenchyme (see fig. 4). I do not think there can be any reasonable doubt, therefore, that this tissue is gradually reverting to its primitive condition of a mesoblastic syncytium, which will later have the power to develop into ordinary connective tissue, and thus give rise to the fibres of the spheno-mandibular ligament.

Another excellent example of retrogression of cartilage to its primitive mesenchymatous condition is afforded by the epiphyal element of the second branchial arch which gives rise to the stylo-hyoid ligament. The latter structure thus does not represent merely the perichondrium of the epiphyal, as is generally described.

I can find no trace of muscle fibres in the situation of the spheno-mandibular ligament in sections of embryos, and am therefore inclined to question Chaine's (*op. cit.*) conclusion that it is transformed muscle tissue.



SOME FACTORS INFLUENCING THE POSITION OF THE SMALL  
INTESTINE. By P. T. CRYMBLE, *Lecturer on Applied Anatomy,*  
*Queen's University, Belfast.*

(Read before the Anatomical Society of Great Britain and Ireland  
at the Middlesex Hospital, 6th March 1914.)

A NUMBER of investigators (Henke,<sup>1</sup> Sernoff,<sup>2</sup> Weinberg,<sup>3</sup> Mall<sup>4</sup>) have recorded observations on the position of the jejuno-ileum. They have drawn their conclusions from normal abdomens, and do not discuss the factors which may influence the position of the small intestine or may account for the various abnormal arrangements of jejuno-ileum which one frequently observes. In this paper conclusions have been drawn from all the material examined, whether normal or abnormal, and an attempt has been made to give reasons for the different arrangements.

Mall is the most frequently quoted observer, and his figures are reproduced in many of the text-books. He examined fifty adults, and forty-one of these were free from peritoneal adhesions and abdominal disease. In thirty-five of these forty-one bodies the jejuno-ileum entered into each of the three main divisions of the lower abdomen, *i.e.* the right and left ilio-lumbar regions and the pelvic cavity.

Addison<sup>5</sup> noted the arrangement of coils, and found the upper third of the jejuno-ileum arranged in horizontal loops in 60 per cent. and the lower third of the jejuno-ileum arranged in vertical loops in 50 per cent. The reason of this arrangement is not discussed.

METHOD AND MATERIAL USED IN THIS INVESTIGATION.

Fifty-six adult human bodies, hardened by injection of formalin, have been examined.

Six of these were frozen for eight days and cut into sections by a hand saw.

<sup>1</sup> Henke, *Archiv für Anatomie*, 1891.

<sup>2</sup> Sernoff, *Internat. Monatsch. für Anat. und Phys.*, 1894.

<sup>3</sup> Weinberg, *Internat. Monatsch. für Anat. und Phys.*, 1896.

<sup>4</sup> Mall, *Reichert's Archiv*, 1897.

<sup>5</sup> Addison, *Journ. of Anat. and Phys.*, vol. xxxv.

In the cases of a girl aged fourteen years, a girl aged twenty years, and a man aged fifty years the sections were horizontal and each slab was made one inch thick.

In two bodies the sections were made by coronal saw cuts, and in the sixth body sagittal sections were made.

The remaining fifty bodies were dissecting-room subjects, very well hardened by formalin injection and immersion in formalin tanks for six to twelve months before being subjected to dissection. In these bodies the abdomen was opened by a crucial incision, and the lower ribs on the left side removed by saw cuts. A sketch of the small intestine was then made on a prepared diagram showing the bony framework and the inner margins of the psoas muscles.

In most cases the course of the small intestine in the pelvic cavity was too complicated to record.

On a second similar diagram the large intestine, liver, stomach, and bladder were sketched.

#### THE NORMAL POSITION OF THE JEJUNO-ILEUM.

The peritoneal cavity may be subdivided into four main regions:—

1. The subphrenic region, or that part lying superior to the transverse mesocolon.
2. The right ilio-lumbar region—a space, triangular in outline, bounded superiorly by the transverse mesocolon, laterally by the lateral abdominal wall, and medianly by the mesentery of the jejunum-ileum and by the right psoas margin.
3. The left ilio-lumbar region—bounded superiorly by the transverse mesocolon and the phrenico-colic ligament, laterally by the lateral abdominal wall, medianly by the jejunum-ileum mesentery, and inferiorly by the left psoas margin and the sacral promontory. It is more extensive than the right ilio-lumbar region, since it extends superiorly to a greater extent and is broader inferiorly.
4. The pelvic region—separated from the ilio-lumbar regions by the sacral promontory and the inner margins of the two psoas muscles.

Of the fifty-six bodies examined only nineteen were free from bladder or stomach distension, enteroptosis, or peritoneal abnormalities.

In six of the nineteen the jejunum-ileum was confined to the left ilio-lumbar and pelvic regions, and in the remaining thirteen the small intestine was distributed over both ilio-lumbar regions and the pelvic region. The amount of small intestine entering the right ilio-lumbar region was, as a rule, much less than that entering the other two regions.

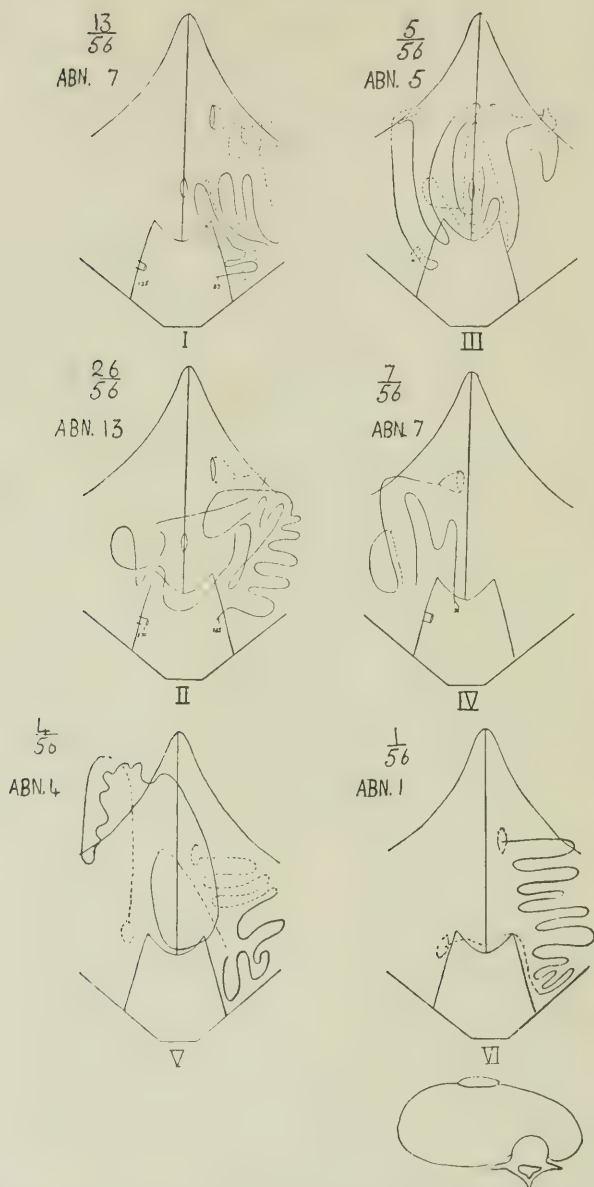


FIG. 1.—Shows the six arrangements of jejunum-ileum found in an examination of fifty-six bodies. Each diagram shows the course of the ilio-lumbar small intestine. The course of the pelvic small intestine is too complicated to figure. The course of the costal margin, mid-line, umbilicus, sacral promontory, inner margin of psoas, the inguinal ligaments, and the pubic crests are shown. The figures at the top left-hand corner of each diagram indicate the number of times the arrangement occurred. ABN. followed by a figure indicates the number of times a disturbing factor was present. *E.g.*, enteroptosis, distended bladder, or abnormal peritoneal fold. It will be noticed that all the cases in groups III, IV, V, and VI were associated with some disturbing factor.

Below group VI is a drawing of a horizontal section which shows the marked increase in the size of the left ilio-lumbar region in a case of lateral curvature, convex to the right.

In twenty-six bodies the small intestine entered both ilio-lumbar regions and the pelvic cavity, and of these twenty-six the following may be recorded:—

Male aged forty-two years:

One loop of jejunum-ileum in the iliac fossa below the cæcum.

L.I.L. (left ilio-lumbar region) . . . . . 1-55 inches.

R.I.L. (right ilio-lumbar region) and P. (pelvis) . . . 56-79 „

Pelvic mesocolon laden with fat.

Large space above the bladder (probably the bladder had been previously distended with urine).

Male aged sixty years, body 9:

Distension of the small intestine due to a colic stricture

Cæcum and ascending colon covered by small intestine.

Male aged sixty years, body 2:

L.I.L. . . . . 1-77 and 96-132 inches.

P. . . . . 78-95 „

R.I.L. . . . . 132-184 „

Pelvic cavity diminished in size by a deposit of extra-peritoneal fat and contained a partially distended and long pelvic colon.

Female aged twenty-eight years:

L.I.L. . . . . 1-26 inches.

P. . . . . 27-46 „

R.I.L. . . . . 47-110 „

Much extra-peritoneal fat in the pelvic cavity. Massive pelvic mesocolon and large appendices epiploicæ.

Male aged thirty-nine years:

Several inches of the small intestine in the median part of the right iliac fossa.

Fundus of the cæcum fixed in an inverted position by a parieto-cæcal fold.

Male aged thirty-one years:

Pelvic cavity occupied by a dilated pelvic colon and contained only a few inches of small intestine. Cæcum and colon very contracted. Valvula coli above the intertubercular plane.

Female aged twenty-seven years:

Low attachment of the transverse mesocolon, the splenic flexure being on the iliac crest.

Male aged forty-eight years:

Pelvic cavity occupied chiefly by the distended pelvic colon and a large hard bladder.

Female aged seventy years:

One loop in a lateral paracæcal fossa, the remainder of the small intestine being confined to the left ilio-lumbar and pelvic regions.

Male aged forty-nine years:

L.I.L. . . . . 1-18 inches.

R.I.L. . . . . 31-48 „

P. Remainder of small intestine.

Total length of small intestine 158 inches.

Left ilio-lumbar region chiefly occupied by the transverse colon.

In a male (body 28, 1912-13):

1-53 inches, with the exception of one loop crossing the right psoas, lay in the left ilio-lumbar region. The remainder lay in the pelvic cavity.



In many of the above cases there is a definite cause for the presence of a considerable quantity of small intestine in the right ilio-lumbar region. In some only a few inches have entered the space.

#### ABNORMAL POSITIONS OF JEJUNO-ILEUM.

1. The small intestine is excluded from the pelvis, and is confined to the ilio-lumbar regions. Present in five.

Causes:—

- (a) Female aged thirty years. Pelvic cavity occupied by a distended rectum and pelvic colon. A large amount of extra-peritoneal fat diminished the size of the pelvic peritoneal cavity.
- (b) Male aged sixty-eight years and a female aged sixty-eight years. Distension of the bladder.
- (c) Male aged seventy-five years. Great distension of the rectum.
- (d) Female aged sixty-nine years. Pelvic cavity occupied by the uterus, a distended rectum, and the pelvic colon.

2. The small intestine is confined to the right ilio-lumbar and pelvic regions, or a few inches only are admitted to the left ilio-lumbar region. Present in seven.

Causes:—

- (a) The distal third or fourth of the transverse colon is fixed to the posterior abdominal wall by an abnormal peritoneal membrane. Present in three cases, *i.e.* a female aged sixty-one years, a female aged sixty-five years, and a female aged eighty years (see figs. 2 and 3 and 21).
- (b) Enteroptosis. Present in two cases, *i.e.* a female aged seventy-six years (see figs. 4 and 5) and a female aged thirty-five years.
- (c) Left ilio-lumbar region occupied by a distended ascending limb of the transverse colon and a distended descending colon. Present in a female aged thirty-nine years.
- (d) Left ilio-lumbar region occupied by the cæcum, a large part of the transverse colon, and the first eight inches of jejunum. Present in a male aged seventy-two years.

3. The small intestine enters the subphrenic region. Present in four.

Causes:—

- (a) Distension of the bladder. Present in a man aged forty-three years.
 

Left ilio-lumbar region	. . . . .	1-89 inches.
Right ilio-lumbar and subphrenic regions	. . . . .	90-172 „

 Some coils of ileum passed upwards in front of the transverse colon, and lay in contact with the right lobe of the liver.



FIG. 2.—Abnormal arrangement of peritoneum. The transverse colon forms a long V-shaped loop, the apex of which lies in the pelvis. The distal third of the transverse colon is adherent to the posterior abdominal wall. This arrangement of colon prevented the entrance of small intestine into the left ilio-lumbar region, and resulted in the cecum and ascending colon being covered by small intestine.



FIG. 3.—Abnormal position of small intestine. Shows the arrangement of the small intestine in the right ilio-lumbar region of the case illustrated in fig. 2. The small intestine occupied the right ilio-lumbar and pelvic regions. The pelvic loops were too complicated to figure. There was no small intestine in the left ilio-lumbar region.



FIG. 4.—Female aged seventy-six years. Marked enteroptosis. The colon was filled by scybalous masses. Right parietocolic fold, behind which was a loop of small intestine. The main mass of the ilio-lumbar small intestine lay between the ascending and transverse colons. Owing to the left ilio-lumbar region being occupied by a stomach distended and low in position, and by a colon laden with scybala, only two inches of small intestine lay in that region.

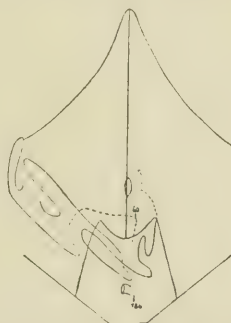


FIG. 5.—Course of the ilio-lumbar small intestine in the female aged seventy-six years, illustrated in fig. 4. Marked enteroptosis, the valvula coli lying at the bottom of the pelvis. Only two inches of small intestine lay in the left ilio-lumbar region.

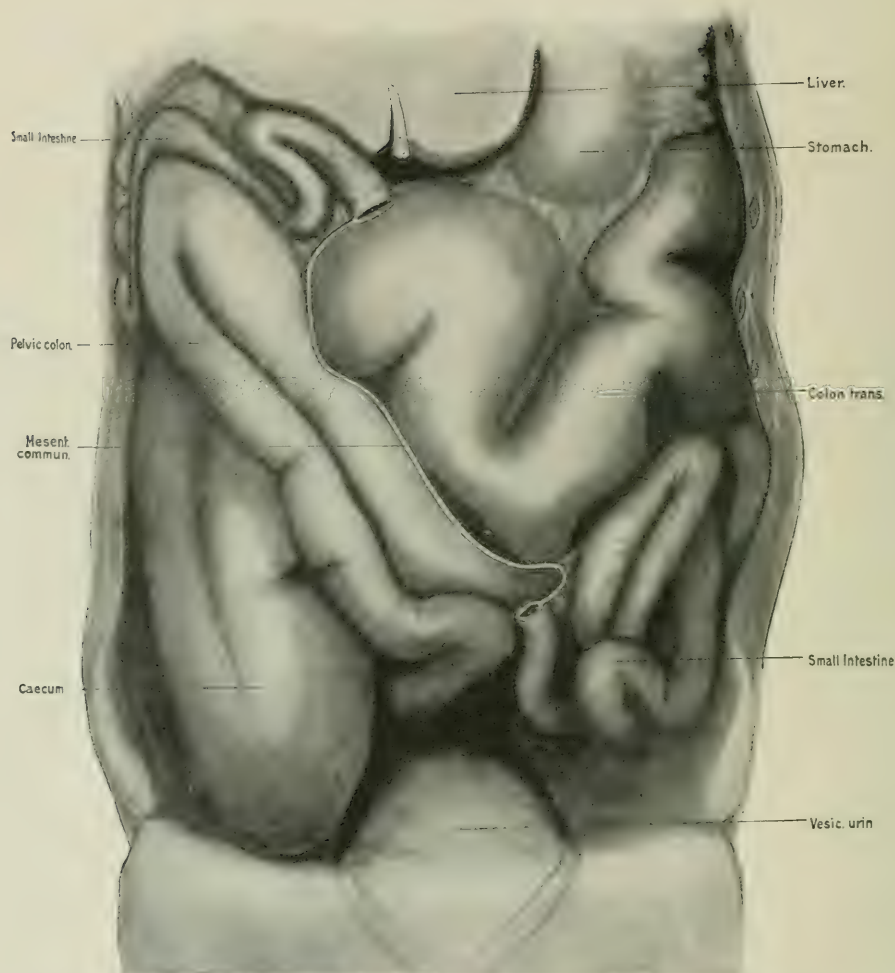


FIG. 6.—Abdominal viscera of a male aged sixty-four years, viewed from the front. The urinary bladder is distended and entirely fills the pelvic cavity. The caecum and transverse colon are enormously distended with soft faeces. The descending and iliac colon, concealed from view by transverse colon and coils of small intestine, are slightly larger than normal. The pelvic colon forms a  $\cap$ -shaped loop, directed upwards and to the right. The apex of this loop and some coils of small intestine are seen lying in front of the liver. They intervened between the liver and the ribs, occupying the right anterior intraperitoneal subphrenic space. This abnormal arrangement of small intestine was due to three factors: (a) the distension of the bladder; (b) the distension of the caecum, ascending and transverse colons; (c) the fixation of the distal five inches of transverse colon to the posterior abdominal wall (see fig. 7).

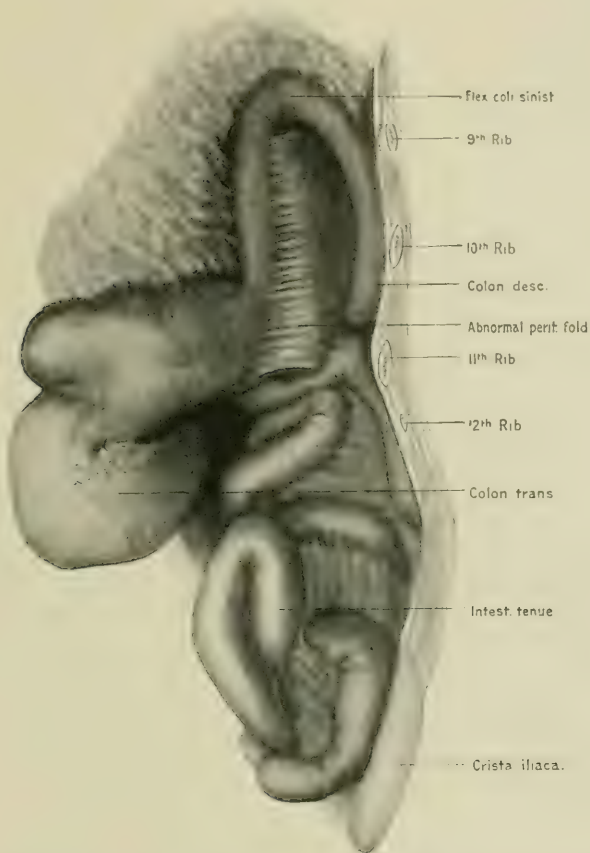


FIG. 7.—Abdominal viscera of a male aged sixty-four years, viewed from the left side. The anterior abdominal wall and portions of the lower four ribs on the left side have been removed. Portions of large and small intestine are exposed. The transverse colon, distended with soft feces, is attached in the terminal part of its course, for a distance of five inches, to the posterior abdominal wall by a peritoneal fold. This fold is attached, posteriorly, median to the descending colon and has produced a marked kink at the left colic flexure (O.T. splenic flexure). It has also prevented jejunum from entering the upper part of the left ilio-lumbar region.



(b) Distended bladder and fixation of the distal five inches of the transverse colon to the left posterior abdominal wall (see figs. 6 and 7). Present in a male aged sixty-four years. Coils of small intestine lay in the right anterior intraperitoneal subphrenic space.

(c) Adhesion between the transverse colon and the left lateral abdominal wall. Present in a female aged seventy-four years.

The small intestine was arranged thus:—

Left ilio-lumbar region . . . . . 1-5 and 75-91 inches.

Right ilio-lumbar region and right anterior

intraperitoneal subphrenic space . . . . . 6-75 „

Pelvic region . . . . . remainder.

(d) Abnormal arrangement of the peritoneum with a free communication between the gastric recess of the lesser sac and the ilio-lumbar region. Present in a female aged sixty-five years, in whom the gastric recess was filled by coils of small intestine. A study of fig. 8 will show that the transverse colon passes below the root of the mesentery and behind the coils of small intestine, and is fixed in this position by adhesion to the posterior abdominal wall. The upper region of the abdomen is completely shut off from the lower region by a peritoneal membrane attaching the proximal fourth of the transverse colon and the great curvature of the stomach to the anterior abdominal wall, and the peritoneal cavity of this lower region passes freely upwards behind the stomach, where it is separated from the bursa omenti minoris by a complete septum bursarum composed of gastro-phrenic and gastro-pancreatic folds.

The bursa omenti minoris and the peritoneal cavity in relation to the liver are normal. A gastro-splenic ligament is present, but it has no connexion with the peritoneal diaphragm above described, and it shows a free lower border.

There are two possible explanations of this condition:—

(1) That the colon rotation has not taken place in the usual manner, and adhesion between the transverse colon and the posterior wall of the lesser sac has been prevented by the coils of small intestine. The lower part of the lesser sac has been invaginated into the gastric recess.

(2) The small intestine has burst through the transverse mesocolon, entered the lesser sac, and then burst through the great omentum, thus forming a free communication between the great sac and the gastric recess.

4. The small intestine is confined to the left ilio-lumbar region. Present in one.

This was a case of spinal curvature in a female aged sixty years. The spine was laterally curved, convex to the right, so that the dorso-lumbar region of the spine lay considerably to the right of the mid-line. There was a very marked increase in the size of the left ilio-lumbar region and a corresponding decrease in the size of the right ilio-lumbar region. The



FIG. 8.—Abnormal arrangement of peritoneum and transverse colon. The transverse colon passed below the root of the mesentery and behind the jejunum-ileum. Throughout its whole course it was closely adherent to the posterior abdominal walls or to viscera lying on the posterior abdominal wall. The left ilio-lumbar region communicates freely with a retro-gastric space. The small intestine occupied the retro-gastric space, the left ilio-lumbar region, and the pelvic cavity.

jejunum-ileum was arranged in transverse loops and only passed out of the left ilio-lumbar region to join the colon (see fig. 1 (vi)).

#### FACTORS INFLUENCING THE POSITION OF THE SMALL INTESTINE.

1. *In the Right Ilio-lumbar Region.*—Normally the caecum, ascending colon, and the proximal third or half of the transverse colon are dilated and are capable of almost entirely filling the right ilio-lumbar region.

If the first part of the transverse colon descends parallel and median to the ascending colon, the probability of small intestine entering this region will be still less.

In nineteen of the fifty-six bodies the small intestine did not enter this region, and in six of these thirteen there was no abnormality, but the space was fully occupied by the distended cæcum and colon. In five of the remainder there was distinct enteroptosis, *e.g.* :—

Male aged sixty-eight years—liver in the right iliac fossa, horizontal part of the duodenum lies below the bifurcation of the aorta.

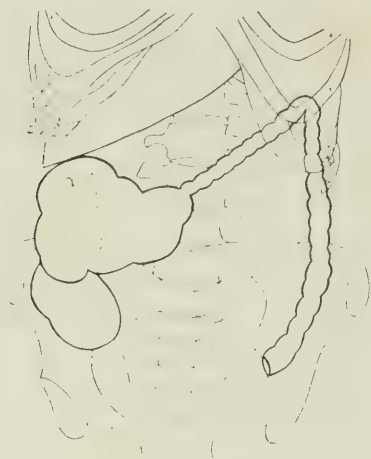


FIG. 9.—Sketch of the colon in a female aged thirty-one years. The first part of the transverse colon is distended and overlies the ascending colon. The remaining part of the transverse colon is much contracted.



FIG. 10.—Course of the right and left ilio-lumbar small intestine in the female aged thirty-one years, illustrated in fig. 9. Ninety-five inches of small intestine lay in the left ilio-lumbar region, the remaining fifty-two inches of small intestine, with the exception of one loop, lay in the pelvis.

The right ilio-lumbar region was occupied by distended colon (see fig. 9) and admitted only a few inches of small intestine.

Female aged eighty years—ptosis of colon and colic flexures.

In the remaining two the colon occupied an abnormal position, a large part being fixed in the right ilio-lumbar region (see figs. 11 and 12).

There are two areas in the right ilio-lumbar region frequently occupied by small intestine, *i.e.* the lower part of the iliac fossa and the space between the cæcum and the transverse colon. Small intestine enters the former where the cæcum is small or occupies a high position (see figs. 13 and 14).

Where the small intestine is unable to enter the pelvic cavity owing to distension of the bladder, rectum, or uterus, an increased amount of it lies in the right ilio-lumbar region; and a similar condition exists if the left ilio-lumbar region is unable to admit small intestine.

Normally the cæcum is in contact with the anterior abdominal wall (see fig. 16), but the jejuno-ileum insinuates itself when it is driven out of the left ilio-lumbar region (see fig. 2).

2. *The Left Ilio-lumbar Region.*—As a rule a large part of the jejunum lies in this region, and when no other viscus encroaches excessively it



FIG. 11.—Abnormal arrangement of the transverse and pelvic colons. The apex of a loop of transverse colon was fixed to the hepatic flexure, the loop and the proximal few inches of the transverse colon forming a closely united triple-barrelled arrangement. Three well-marked angulations were present (see arrows). The limbs of a loop-shaped pelvic colon were closely united at the base of the loop.



FIG. 12 —Arrangement of the ilio-lumbar small intestine in a male aged fifty-two years, in whom the transverse colon was abnormally arranged and prevented the small intestine entering the right ilio-lumbar region (see fig. 11).

arranges itself in horizontal loops. The transverse colon lies anterior to this jejunum, and the descending colon lies posterior to it. The relation of the iliac colon is variable, being at times covered by small intestine and at times in contact with the anterior abdominal wall.

The various conditions which prevent the entrance of small intestine into this region, *i.e.* abnormal peritoneal fold, enteroptosis, dilated colon, are mentioned previously under Abnormal Positions of Small Intestine. In addition to these, one may mention three pathological conditions, *viz.*, enlarged spleen, enlarged kidney, enlarged left lumbar lymph glands.



The last one was associated with new growths of the left testis, and the small intestine was forced into the right ilio-lumbar region. Distension of the stomach drives the small intestine from this region.

In one case (fig. 1) all the small intestine, with the exception of the pars cæcalis ilei, lay in the left ilio-lumbar region and was arranged in a series of horizontal loops.

3. *The Pelvic Cavity*.—This contains the chief mass of the ileum.

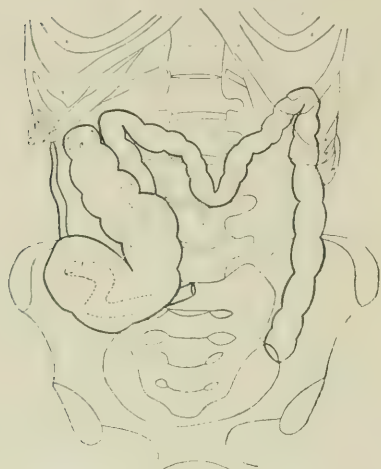


FIG. 13.—Male aged sixty-three years. The fundus of the caecum is fixed in a high position by a pre-renal appendix. Kinks are present in the pars cæcalis ilei and at the hepatic flexure. The first few inches of the transverse colon descend retroperitoneally behind the ascending colon.

The high position of the caecum permits small intestine to enter the lower part of the right iliac fossa (see fig. 14).

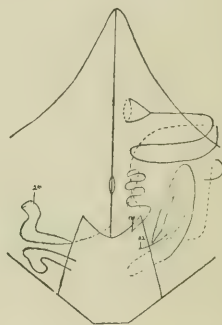


FIG. 14.—Male aged sixty-three years. Course of the right and left ilio-lumbar small intestine. A loop of ileum occupies the lower part of the right iliac fossa. The first eighty-two inches of small intestine is seen lying in the left ilio-lumbar region. Inches 82-178 occupied the pelvis, but are not figured. The portion 178-210 re-entered the left ilio-lumbar region and then passed downwards and to the right towards the valvula coli. Owing to the high position of the caecum, a loop of ileum was permitted to enter the lower part of the right iliac fossa.

Owing to the greater capacity of the female pelvic cavity there is usually more pelvic small intestine in the female than in the male.

The terminal portion of the ileum passes upwards and forwards from the bottom of the pelvic cavity to the valvula coli, situated in the right iliac fossa. During its course it lies against the right lateral wall of the pelvis, and as it crosses the right psoas margin it can be rolled under the palpating fingers and can be easily recognised, especially during contraction of the psoas muscle.

In a minority of cases it passes obliquely downwards from the left ilio-lumbar region to the right iliac fossa.

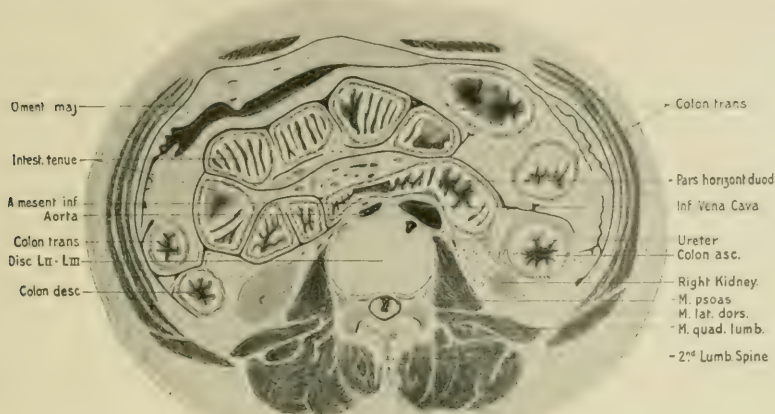


FIG. 15.—Horizontal section of a girl aged fourteen years, through the disc between the second and third lumbar vertebrae. The right ilio-lumbar region is chiefly occupied by transverse colon, ascending colon, and duodenum.

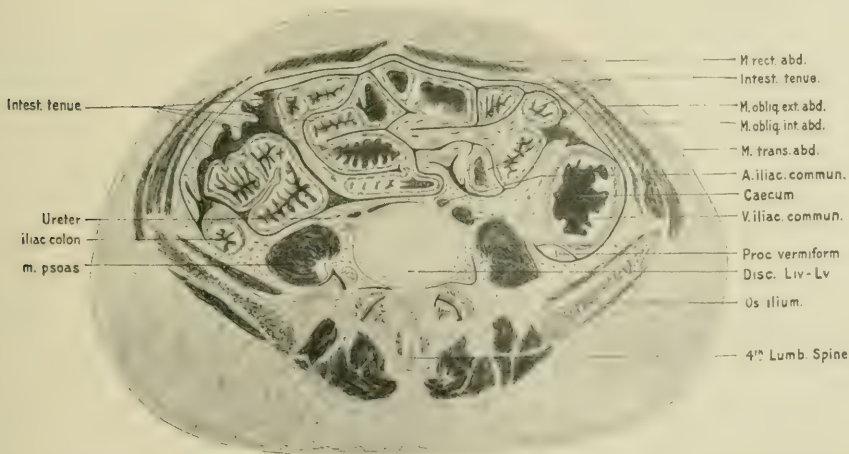


FIG. 16.—Horizontal section of a girl aged fourteen years, through the disc between the fourth and fifth lumbar vertebrae. The cæcum, as usual, fills the right iliac fossa, and is lying in contact with the anterior abdominal wall. The iliac colon is in its normal contracted condition and is covered by small intestine.

The fixation of the pelvic colon to the left side of the pelvic cavity influences the ileum to occupy the right side of this region.

The following conditions diminish the capacity of the pelvic cavum peritonæi and more or less completely prevent the ileum entering:—

- (a) Excessive amount of extra-peritoneal fat.
- (b) Distension of the bladder.
- (c) Distension of the rectum.
- (d) Enlargement of the uterus.
- (e) Distended pelvic colon occupying this region.

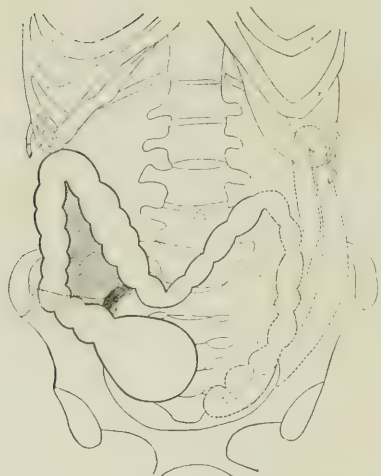


FIG. 17.—Female aged sixty-seven years, showing enteroptosis and a median paracolic fossa formed by a peritoneal membrane connecting the ascending and transverse colons. This fossa contained a twenty-seven-inch loop of ileum.

The portion of transverse colon indicated by dotted lines was overlain by jejunum.



FIG. 18.—Sketch of the ilio-lumbar small intestine in a female aged sixty-seven years (see fig. 17).

4. *In the Subphrenic Region.*—Small intestine came in contact with the diaphragm in four of the fifty-six cases. In three of these a peritoneal abnormality accounted for the arrangement, and in the fourth case there was a distended bladder.

As a rule the small intestine is forced upwards in front of the transverse colon into contact with the right lobe of the liver and the costal margin, but in the very rare case illustrated in fig. 8 the small intestine passed upwards into the gastric recess of the lesser sac.

#### ARRANGEMENT OF JEJUNUM IN LEFT ILIO-LUMBAR REGION.

The arrangement of the jejunum in the left ilio-lumbar region was recorded in forty-five bodies.

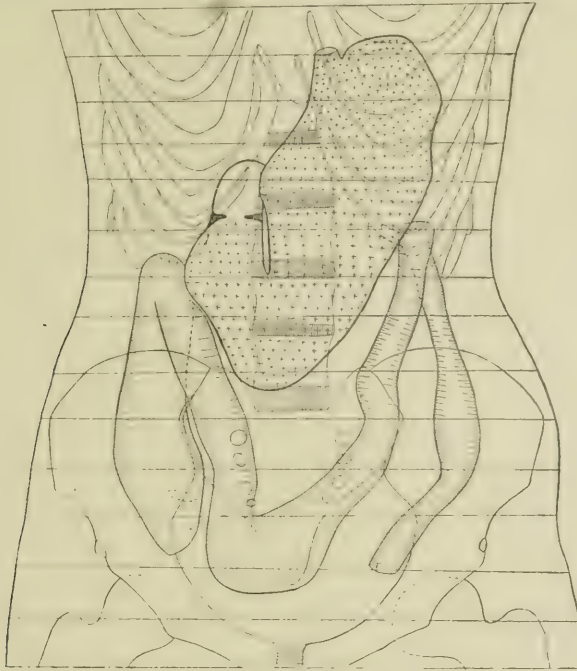


FIG. 19.—Reconstruction of the stomach and colon from a series of horizontal sections, through the abdomen of a girl aged twenty years. There is marked enteroptosis.

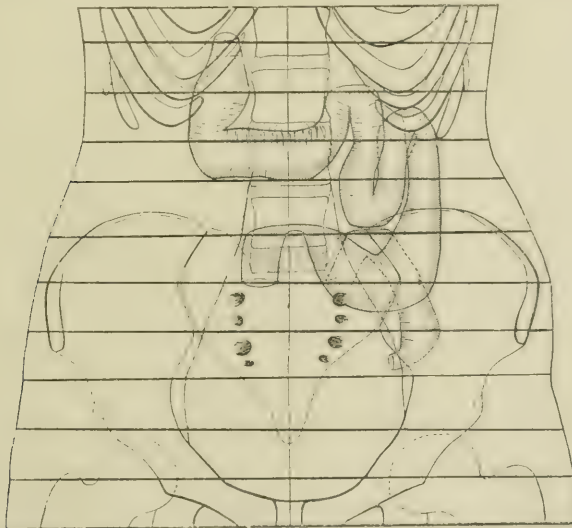


FIG. 20.—Reconstruction of the duodenum and left ilio-lumbar small intestine from a series of horizontal sections, through a girl aged twenty years. There is marked enteroptosis, and, with the exception of the few loops lying in the left ilio-lumbar region, all the jeuno-ileum lay in the pelvic cavity.



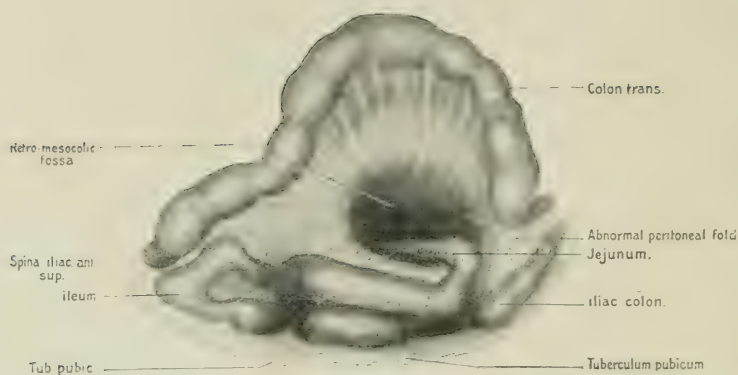


FIG. 21.—Female aged eighty years. All the jejunum-ileum lay in the pelvic cavity, except a loop lying anterior to the cæcum and the first five inches of jejunum, which lay in a retro-mesocolic fossa in the left ilio-lumbar region. This fossa was bounded on the right and anteriorly by the transverse meso-colon. On the left it was bounded by an abnormal peritoneal fold which fixed the terminal fourth of the transverse colon to the posterior abdominal wall, median to the iliac and descending colons. The result of this arrangement of peritoneum is the almost complete absence of jejunum-ileum from the left ilio-lumbar region and the presence of jejunum-ileum in front of the cæcum.

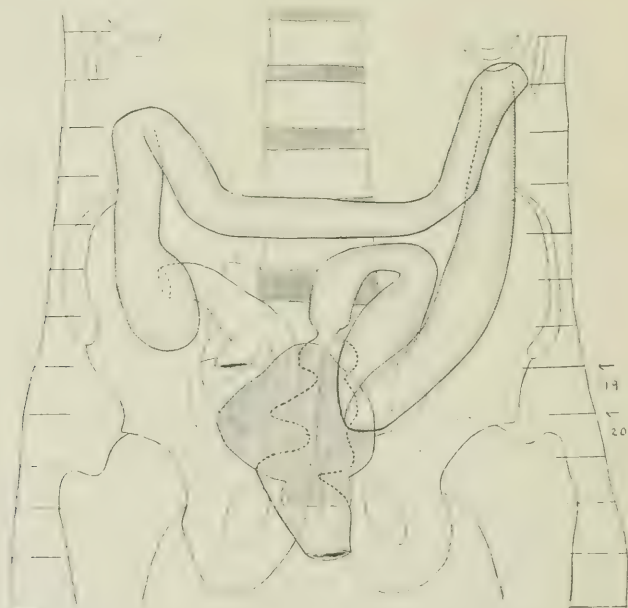


FIG. 22.—Reconstruction of the urinary bladder, the terminal portion of the ileum, the cæcum, the colon, and the rectum, from a series of horizontal sections through a man aged fifty years. Rectal constrictions are well marked. The upper surface of slab 19 is seen in fig. 24.

In eleven the jejunum was arranged in horizontal loops, and all these abdomens were normal.

In twenty the jejunum was arranged in vertical loops; but of these twenty, fourteen showed some encroachment on the left ilio-lumbar region by either a distended stomach (ten cases) or an abnormal colon (four cases).

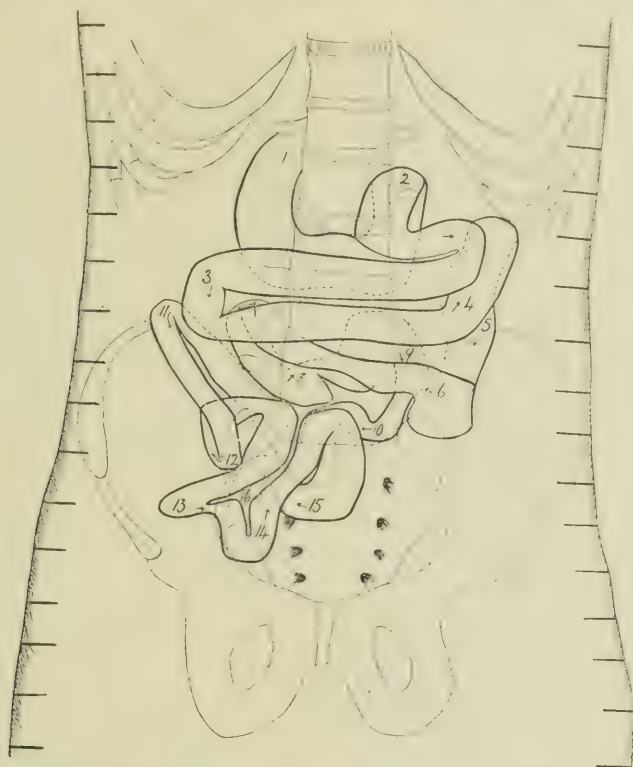


FIG. 23.—Reconstruction of the small intestine of a man aged fifty years. It is unusual to find the small intestine so evenly distributed between the right and left ilio-lumbar regions. Reference to fig. 22, where a reconstruction of the bladder and colon is illustrated, will demonstrate the factors controlling this arrangement. The descending and iliac colons are abnormally distended. The bladder occupies a large part of the pelvic cavity and is in a distended condition.

In fourteen the arrangement could not be classified owing to irregularity of the loops, and ten of these fourteen showed abnormalities, *i.e.* six—no small intestine in the pelvic cavity; two—distended stomach; two—abnormal colon.

It would appear, therefore, that the upper part of the small intestine is normally arranged in horizontal loops, but that this arrangement gives

place to vertical loops in the presence of any factor diminishing the left ilio-lumbar small intestine space.

In support of this conclusion it may be noted that in the case of enlargement of the left ilio-lumbar region, due to lateral curvature, the entire mass of jejunum-ileum was accommodated in this space and arranged itself in horizontal loops.

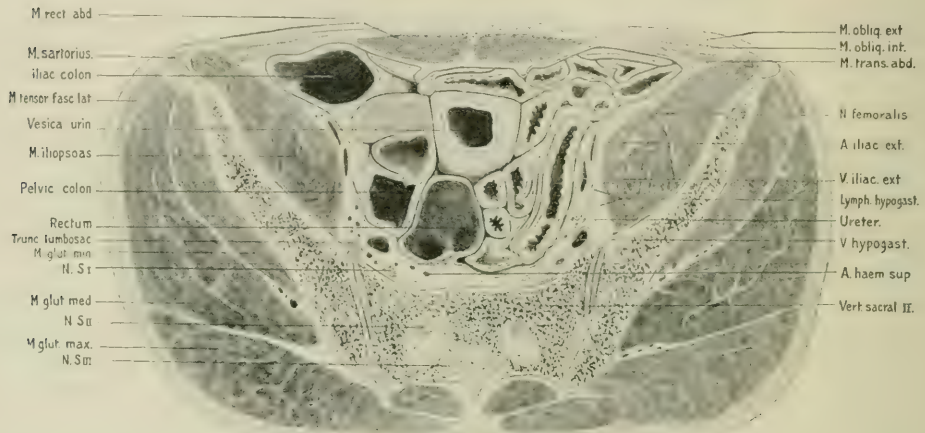


FIG. 24.—Horizontal section through the pelvis of a man aged fifty years. The fundus of a distended bladder, separated from the anterior abdominal wall by a coil of ileum, is seen in the centre of the section. The left half of the pelvic cavity is occupied by pelvic colon. Numerous coils of ileum fill up the right half of the pelvic cavity. The level of this section in the reconstruction (fig. 22) is indicated by the arrow above the figure 19.

#### APPLIED ANATOMY.

The interpretation of the various percussion notes obtained over the abdomen is facilitated by a clear conception of the probable position of the small intestine, *e.g.*, the absence of the usual caecal note may lead the observer to the discovery of an abnormal peritoneal arrangement in the left ilio-lumbar region whereby small intestine is forced between the caecum and the anterior abdominal wall, or the loss of the caecal note may be due to distension of the small intestine.

It must be noted that the position and relations of abdominal viscera may be altered by opening the cavum peritonæi in the living person, since the intra-abdominal positive pressure will drive the mobile small intestine towards the opening.

The X-ray examination of the bismuth meal shows the jejunum-ileum bismuth as scattered dark areas, chiefly in the pelvis. No doubt in the erect position the main mass of the small intestine lies in the pelvis.

SUMMARY.

1. Fifty-six adult bodies were examined.
2. Six bodies were frozen and cut into sections.
3. In twenty-six bodies the small intestine entered both ilio-lumbar regions and the pelvic cavity.
4. In thirteen bodies the small intestine was confined to the left ilio-lumbar and pelvic regions.
5. In five bodies the small intestine was confined to the ilio-lumbar regions.
6. In seven bodies the small intestine was confined to the right ilio-lumbar and pelvic regions.
7. In four the small intestine entered the subphrenic region.
8. In one the small intestine was confined to the left ilio-lumbar region.
9. In the normal abdomen the jejunum-ileum lies in the ilio-lumbar regions and the pelvic cavity, or is confined to the left ilio-lumbar region and the pelvic cavity.
10. *Physiological Alterations.*—The pelvic small intestine is forced into the ilio-lumbar regions by distension of the bladder, rectum, or uterus. Distension of the cæcum and ascending colon forces small intestine out of the right ilio-lumbar region, and distension of the stomach forces small intestine out of the left ilio-lumbar region. Small intestine lies anterior to the upper end of a distended bladder (see fig. 24).
11. *Anatomical Variations.*—Fixation of the distal third of the transverse colon to the posterior abdominal wall confines the small intestine to the right ilio-lumbar and pelvic regions, and is associated with the presence of small intestine in front of the cæcum.
12. Enteroptosis is associated with the absence of small intestine from the right ilio-lumbar region. In marked enteroptosis the small intestine is almost entirely confined to the pelvic cavity (see figs. 19 and 20).
13. When there is a sufficient amount of room the jejunum tends to arrange itself in horizontally placed coils in the left ilio-lumbar region.
14. The presence of small intestine in the subphrenic region is abnormal, and is associated with some peritoneal variations or excessive distension of some viscus.



A PLEURAL FOLD CONTAINING THE VENA AZYGOS. By JOHN  
R. D. HOLTBY, M.B., B.S., *Chief Demonstrator of Anatomy, Trinity  
College, Dublin.*

CASES in which an extra lobe or process of the right lung is found accommodated within a pleural cul-de-sac and associated with an irregularity in the course of the vena azygos are sufficiently rare in the human subject to merit record. Professor Waterston informs me that the condition

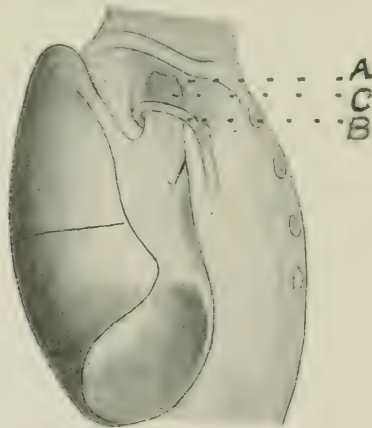


FIG. 1.—The specimen viewed from the front; the lung is drawn backwards and outwards.

A, pleural fold; C, accessory process; B, vena azygos.

is constant in the porpoise, and if the explanation here advanced be correct, it is remarkable that it is not more commonly met with in man. Specimens have been described and theories advanced as to its causation by Chiene, Cleland, Collins, and Geddes in this country, and abroad by numerous observers, more especially Fischer, Bluntschli, and Du Séjour.

The specimen here described was obtained from an aged female subject submitted for dissection in November 1913.

The thoracic cavity showed no other anomalies and the pleura was free from adhesions. On drawing back the right lung, a distinct pleural fold was seen passing down from the thoracic apex (fig. 1). Lying between

this fold and the mediastinal pleura was a tongue-shaped process of pulmonary tissue which had its root on the inner surface of the highest lung lobe just behind the hilum. The cleft between this process and the main lung mass was deepest at the posterior border, where it was only separated from the great oblique fissure by a thin bridge of pulmonary substance. In conformity with this, the lower border of the pleural fold showed its greatest curvature posteriorly. The lower margin of the fold lay opposite the disc between the 5th and 6th dorsal vertebrae, and contained between its layers the vena azygos.

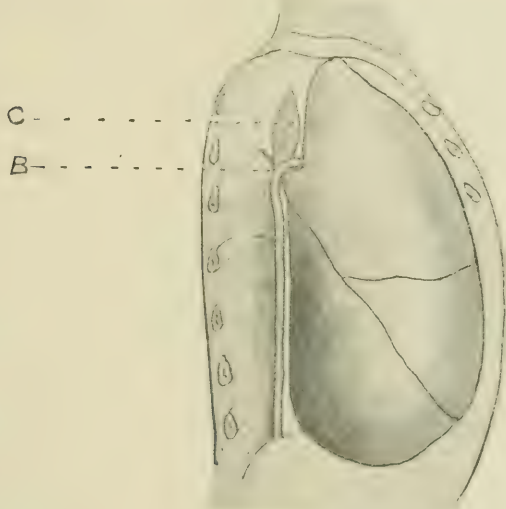


FIG. 2.—The specimen viewed from behind; the lung is drawn forwards.

C, accessory process of lung; B, vena azygos.

The accessory pleural sac lying to the medial side of this fold, or meso-azygos, extended upwards to the lower border of the 7th cervical vertebra. Anteriorly it was bounded by the junction of the fold with the mediastinal pleura along the line of the vena cava superior; posteriorly by its junction with the vertebral pleura. The superior intercostal vein ran forwards and downwards from the posterior thoracic wall between the layers of the fold to reach the vena azygos in its lower border.

The pleural apex seemed, therefore, to have been divided by the vena azygos, which, cutting it rather to the medial side of its central point, pulled down from it a double fold and so separated the pleural dome into

two portions, a small medial and a large lateral, the former accommodating the accessory process, the latter the apex of the highest lung lobe.

The accessory process received a bronchus from the main epiarterial division; the vein from it passed in a curved manner over the upper and anterior border of the hilum to reach the upper main pulmonary vein.

A likely explanation of the causation of this anomaly is obtained by studying sections of embryos varying between 5 and 20 mm. lengths. Figs. 3 and 4, which are photographs from the well-known model of Piper's embryo (6.8 mm.), show most of the points with which we are concerned.

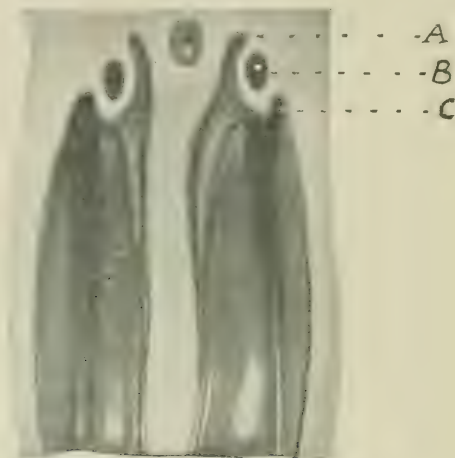


FIG. 3.—Posterior half of coronal section  
(model of Piper's embryo).

A, medial pleural apex; B, vena card. post.; C, lateral pleural apex.

In fig. 3 the elevation on the posterior body wall produced by the vena cardinalis posterior is seen to arch forward at its upper end, so that the vein is here carrying with it a fold of the primitive pleural membrane. This fold divides the apex of the pleuro-coelomic cavity into medial and lateral segments, of which the medial is the higher and the more pronounced.

Fig. 4 shows the relationship of the lung bud to this fold: the lung, growing laterally, passes close to its lower border.

At a later stage the lung, expanding on the lateral aspect of the fold, will grow upwards into the lateral pleural apex. With the downward descent of the thoracic organs, the medial apex is pulled downwards, and so disappears: the vena azygos thus comes to occupy its normal relationship to the mediastinum and pleura.

But if before the medial pleural apex has quite disappeared a down-

ward pull on the fold should cause it to impinge, at the point where its curvature is greatest, posteriorly, against the lung bud so as to separate a process of pulmonary tissue, this process, so formed, would, as it grows and expands, push the medial pleural apex upwards again and prevent its disappearance.

Bluntschli and Fischer suggest that delayed transference (owing to late formation of some of its tributaries) of the vena subclavia from the vena cardinalis posterior to the vena cardinalis anterior may result in an outward pull of the fold at a later period than usual, and this, in conjunction



FIG. 4.—Anterior half of coronal section (model of Piper's embryo).

A, medial pleural apex; B, vena card. post.; D, fold containing vena card. post.; E, lung bud.

with the downward pull of the general thoracic contents, makes it more likely to produce a cleft in the lung substance.

The condition is a survival of a constant embryonic arrangement, and it is remarkable that the factors which occasionally cause its appearance do not more frequently give rise to its production.

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 VOL. XLIX. (THIRD SER. VOL. X.)—JAN. 1915.





CHARLES BARRETT LOCKWOOD.

## In Memoriam.

CHARLES BARRETT LOCKWOOD.

*Born Sept. 23, 1856, died Nov. 8, 1914.*

THE announcement of the death of Mr Lockwood has been to all those Anatomists who have been associated with him a cause of unfeigned sorrow. He had been so closely connected with the Anatomical Society from its earliest days, that his removal from our ranks leaves a blank which cannot be filled. In a sense, he was the founder of the Society, for, although for some years before its institution Sir G. Humphry had contemplated the formation of an Association of British Anatomists, it did not take definite shape until Mr Lockwood was associated with him in its organisation. The scheme was discussed during several week-end visits to Cambridge, and, when we three had arrived at a definite plan for the Society, Mr Lockwood willingly undertook the arduous task of enlisting the interests of the teachers of Anatomy in the London schools. As a result of his labours, the first preliminary meeting took place early in 1887 in Mr Lockwood's house, and the first public meeting was held at St Bartholomew's on May 6, 1887, with Humphry as President and Lockwood as Secretary.

In its early days it owed much of its vitality to his unremitting and judicious labours, both in his official and private capacity. His sound common-sense, logical mind, and untiring energy were important factors, contributing more than anything else to its development and growth, and it was as an acknowledgment of this obligation that in 1902 he was unanimously chosen as President.

The papers which he communicated to the Society were many and valuable, especially those on "The Development and Transition of

the Testis" (vol. xxi. 6, 35, and xxii. 38, 461, 505), "The Muscles, Ligaments, and Fasciæ of the Orbit" (xx. 1), and on "The Development of the Great Omentum and Transverse Mesocolon." Besides these, he also contributed shorter memoirs on "An Abnormality of the Fissure of Rolando" (xxiii. 16), on "A Right Aortic Arch" (xxiv. 4), on "Interruption of the Small Intestine" (xxiv. 13), on "Fossa around the Cæcum" (xxvi. 130), on "Adrenal Structures in the Inguinal Canal" (xxxiv. 79), and on "The Lymphatics of the Vermiform Appendix" (xxiv. 9).

Although of late his growing absorption in the elucidation of practical points in operative surgery took his attention away from Anatomy, yet he attended the meetings as regularly as his many professional engagements permitted, and his zeal in promoting its interests did not flag. All those who were associated with him in its work felt for him a very genuine and high esteem as an acute observer, a logical thinker, who combined an earnest interest in the morphological side of Anatomy with a clear conception of the bearings of the science on its practical application to surgery. It was the irony of fate that he who had done so much to elucidate the clinical history of septicæmia, especially in connexion with abdominal operations, should have died of this disease as a result of a slight puncture in operating for appendicitis.

His loss to anatomical science is very great, for in these days of specialisation the number of investigators in Anatomy who are at the same time practical surgeons is rapidly diminishing, and the divorce is a distinct disadvantage as regards the educational value of Anatomy to the medical student.

We owe to the kind courtesy of the Editor of the *Lancet* the excellent portrait of Mr Lockwood on p. 240.

A. M.

# JOURNAL OF ANATOMY AND PHYSIOLOGY

VERTEBRAL COLUMN WITH SIX AND A HALF CERVICAL  
AND THIRTEEN TRUE THORACIC VERTEBRÆ, WITH  
ASSOCIATED ABNORMALITIES OF THE CERVICAL  
SPINAL CORD AND NERVES. By JAMES C. BRASH, M.A.,  
M.B., B.Sc., *Demonstrator of Anatomy, University of Leeds.*

## INTRODUCTION.

THE vertebral column and portion of spinal cord described in this paper were obtained from a male subject, aged 61, dissected at Leeds during the Summer Term, 1913. The column is not complete, as it suffered that annoying damage which frequently overtakes interesting abnormalities discovered after dissection has been in progress for some time. The laminae from the 6th cervical downwards have been sawn through, the spinal cord from the same level destroyed, and the sacrum broken through its lower half. This damage, however, causes no serious difficulty, as the main interest lies in the intact cervical region; and although, during the subsequent removal of the portion of the cervical cord which had been left, the roots of what ultimately proved to be the single representative on the right side of the 4th and 5th left cervical nerves were found to be torn across at their point of exit from the dura mater, even this, though particularly annoying, makes no difference to the accurate description of the parts.

Some irregularities of the spines and laminae of the cervical vertebrae having been observed during the dissection of the back, and a well-developed pair of 13th ribs discovered, a careful examination was made of the 1st rib region and the brachial plexus; with the result that the 1st ribs were found to be entirely ordinary in appearance, and the plexus apparently normal on the left, but postfixed on the right. This condition was seen to be associated with a reduction of the number of the cervical nerves on the right side to seven; and, as the transverse processes numbered only six, it



was thought that there might be complete absence of half a vertebra, a supposition which was subsequently proved to be correct.

It was found, further, that the 13th ribs were associated with the presence of an additional true thoracic vertebra, the lumbar and sacral regions possessing five each, and the coccygeal four segments. The vertebral formula is therefore  $C6\frac{1}{2}T13L5S5Co4$  (fig. 1).

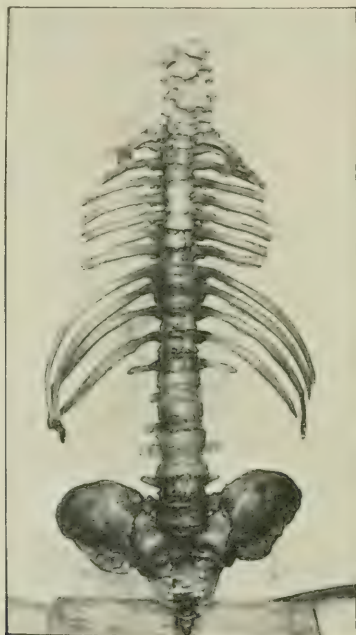


FIG. 1.—Vertebral column.  $C6\frac{1}{2}T13L5S5Co4$ .

The objects of this paper are: (1) to describe the vertebral column, the portion of cervical spinal cord, and some associated structures, with a short account of previous records of similar vertebral deficiencies; (2) to discuss the causation of the condition, and note its surgical interest.

## PART I.

### THE VERTEBRAL COLUMN.

CERVICAL (figs. 2 and 3).—The main interest lies in the cervical region, as there is a clear and complete absence of the right half of the 3rd vertebra. As a result of this absence there is a lateral curvature of the whole region, complicated by firm ankylosis of the remaining left half of the 3rd with

the 4th and 5th vertebræ. There is also some distortion of the other cervical vertebræ, and all show considerable lipping of the bodies and articular processes, such as is often found in the neck of old subjects. The lipping of the bodies is best developed where support is required as a result of the curvature, the upper border of the 6th being pulled out on

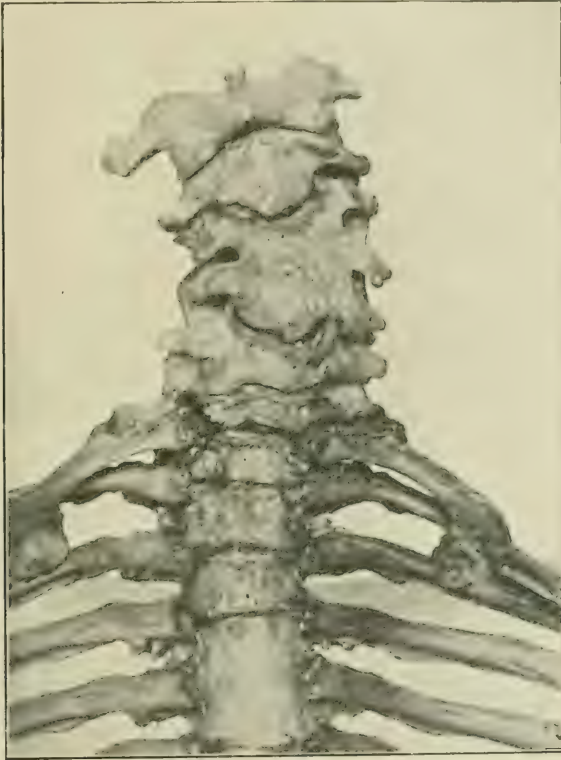


FIG. 2.—Cervical and upper thoracic region. Note the 1st ribs and the ankylosed vertebræ.

the left side, the lower on the right, to form strong buttresses, corresponding depressions being found above and below.

The ATLAS is stout, the posterior arch being especially thick, with a bifid tubercle; the left transverse process is partially broken off.

The AXIS possesses a well-marked occipital facet on a small process of bone separated from the main part of the odontoid process by a shallow constriction. Of the inferior articular surfaces, the right is rough and irregular, measures 18 mm. coronal  $\times$  9 mm. sagittal, and extends on to the

lamina and posterior part of the transverse process; the posterior portion looks directly downwards. The left is small, oval, slightly concave, and somewhat smooth; it measures 7 mm. coronal  $\times$  9 mm. sagittal.

The right lamina is deeper than the left, and both parts of the spine, which is strong and bifid, are twisted to the right.

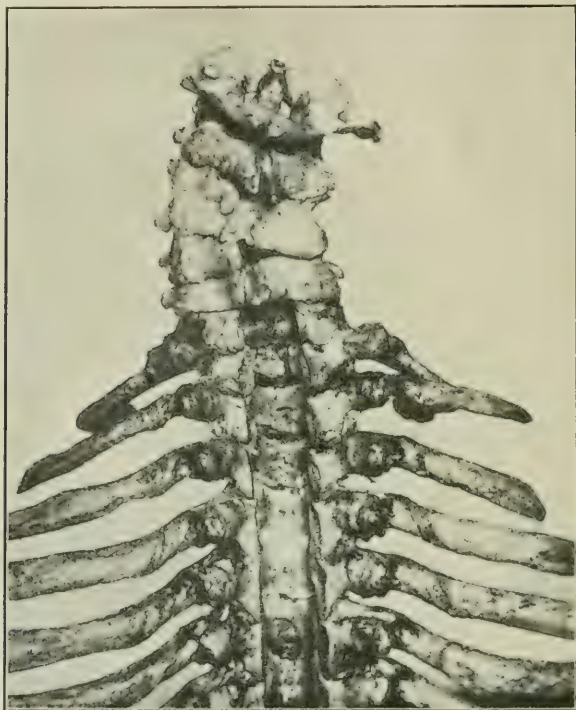


FIG. 3.—Cervical and upper thoracic region.

COMPOSITE PIECE (R., 3rd and 5th; L., 3rd, 4th, and 5th).—*Bodies*.—The  $2\frac{1}{2}$  bodies are fused to form one mass. The lines of fusion between the two halves on the right side, and between the 4th and 5th halves on the left, are distinctly visible in front and partly behind; but the lines between the upper half on the right and the 3rd and 4th halves on the left are not so distinct, and it is impossible to decide whether the odd half is 3rd on top of 4th, or 4th wedged between 3rd and 5th. On scraping the upper surface, however, the appearance, especially from behind, was such as to suggest that the odd half belongs to the 3rd vertebra (fig. 4).

An X-ray photograph (fig. 5) shows clearly the line between the two

right halves, and also between the three left halves, but there is no clear line between either of the 3rd and 4th left halves and the upper half on the right side: and, as the lower left half apparently projects as much below the right half as the upper left half does above it, the appearance is such as to suggest that the right half may correspond to either of the left halves, or indeed to both, *i.e.*, that the condition is doubling of the left half of a single vertebra. This appearance in the X-ray photograph is, however, largely due to a superficial indentation on the anterior part of the lower border of the 4th vertebra, and on examining a coronal section through the middle of the fused mass, the line representing the intervertebral disc

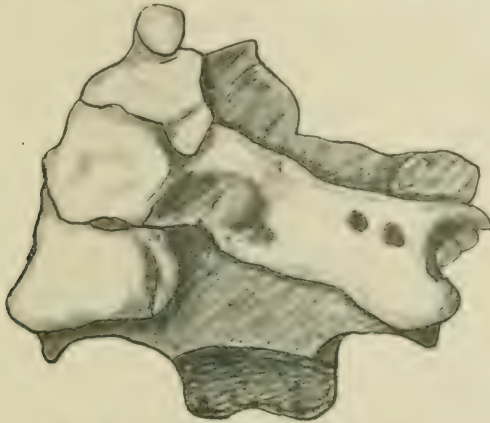


FIG. 4.—Composite piece, posterior aspect.

between the 5th and the two halves above it is seen to be nearly straight though oblique, thus strengthening the suggestion that the odd half is the upper and belongs to the 3rd vertebra. It will be seen later that the arrangement of the nerve roots upsets this suggestion, and, in fact, as the right nerve which corresponds to the 4th and 5th left emerged *between* the two right halves of the composite piece, it is proved that the upper half must be the 3rd, and as there is no question that the lower part is a complete 5th, the absent half *must* be 4th. Such a conclusion drawn from the bones alone could only have been a matter of opinion.

*Transverse Processes.*—There are two on the right side and three on the left, the upper left being associated with the pedicle and half-body of the 3rd in the usual way. The foramina transversaria are distinctly larger on the right side, that of the 5th on the left side, encroached on by lipping of the body, being the smallest. There is partial subdivision of the 4th left by a tiny spicule springing from the medial end of the posterior bar of the transverse process.



The *pedicles* and intervertebral foramina call for no special remark, save that the right 4th-5th foramen is partially subdivided by a small bar of bone stretching from the back of the right side of the 5th body to the 5th pedicle near its posterior end.



FIG. 5.—X-ray photograph from the front.

*Articular Processes.*—The surfaces of the superior, of which the right, belonging to the 4th vertebra, is large, rough, and with lipped edges, and the left, belonging to the 3rd vertebra, is small and smooth, are similar to the inferior articular surfaces of the axis already described. The right, of which the posterior portion looks directly upwards, extends towards the body and laterally overhangs the vertebral notch and a deep groove on the side of the fused arches, extending medially half-way along the lamina. The inferior, both belonging to the 5th vertebra, are fairly

equal in shape and size; the right is slightly concave, the left flat, distinctly lipped laterally, and slightly eburnated. Of the others, on the left side fusion is only partial, particularly between the 4th and the 5th, and there is not much alteration in relative position; on the right side there is complete fusion, of which there is only slight indication towards the intervertebral foramen. The portion of the arch bearing them is compressed so that there is a deep groove overhung by superior and inferior articular processes.

*Laminae* (figs. 3 and 4).—On the left side the three are distinctly seen, as they are only partially fused together. Their greatest depths are: 3rd, 10 mm.; 4th, 12 mm.; 5th, 15 mm. The 3rd slightly overlaps the 4th near the spines, and there is a distinct interval, 8 mm. long, between the 4th and the 5th near their middle. The 3rd and the 5th both end free in a half-spine, the 5th being much more prominent and in the middle line, which the 3rd just fails to reach. The 4th, maintaining its depth, is fused to a plate on the other side only slightly deeper and representing the 4th and 5th right laminae.

On the right side the two laminae are almost completely fused, the composite nature of the resulting lamina being indicated only by two small foramina near the lateral end and about one-third from the superior border, and by three smaller still at the medial end and near the middle. The greatest depth of the plate is 18 mm., and it narrows only slightly at the medial end, where it is fused, as stated, to the 4th left lamina. The resulting composite spine has been slightly damaged by the saw, but there is clear indication that it is bifid and that the left half is double.

**SIXTH CERVICAL.**—*The body* is very irregular; it measures antero-posterior 2 cm., transverse 3.3 cm., posterior depth 1.4 cm. right, 7 cm. left. Its anterior edges are markedly lipped, the superior on the left, the inferior on the right side, in each case a process of bone convex anteriorly and roughly concave posteriorly coming in contact with and overlapping the corresponding edge of the 5th and 7th. The superior of these processes is supported on two rounded pillars of bone which project on the front of the body with a small recess between them. Both superior and inferior faces are extended by the lipping, and on the left side the superior is markedly deepened, the inferior irregularly convex. The right *transverse process* is a trifle more broadly spread than the left, and a spicule cuts off a small posterior part from the foramen in each. The left pedicle is apparently shortened by the overhanging of the lipped body.

*Articular Processes.*—The surface of the right *superior* (1.4 × 1 cm.) is fairly regular, the left (7 × 7 cm.) is smaller, irregular, and eburnated. The left *inferior* (1.1 × 1 cm.) is also irregular and slightly eburnated, and

the anterior portion looks directly downwards; the right ( $1.3 \times 1.2$  cm.), not so irregular and not eburnated, resembles the right superior. The left processes are nearer each other than the right, the depth of the articular column being fairly normal on the right, but shortened on the left: from the highest point of the superior to the lowest of the inferior is on the right 2.4 cm., on the left 1.7 cm. The general feature of the 6th cervical is therefore that it is deeper on the right side than on the left, as seen in body, laminae, and articular processes.

The 7TH CERVICAL repeats the features of the 6th, though in a less marked degree. The body measures in depth on the right 1.3 cm., on the left 1 cm., while the articular columns are, right 2.5 cm., left 2 cm. The left superior articular surface is markedly convex from before backwards and outwards; the anterior portion looks directly upwards. The laminae and spine are lost.

The right *lamina* (1.5 cm. at both ends) is slightly deeper than the left (1.5 cm. at the outer to 1.1 cm. at the inner end). The spine is slightly bifid and twisted to the right.

The following are the measurements of the articular surfaces:—

			Right.		Left.	
			Coronal.	Sagittal.	Coronal.	Sagittal.
2nd	Inf. . .		1.8 cm.	1.6 cm.	.7 cm.	.9 cm.
3rd, 4th, 5th L.	Sup. . .		1.9 "	1.9 "	.7 "	.9 "
4th, 5th R.	Inf. . .		1.4 "	1.0 "	1.2 "	1.1 "
6th	Sup. . .		1.4 "	1.0 "	.7 "	.7 "
						1.5 (oblique) 1.0 (oblique)
	Inf. . .		1.3 "	1.2 "	1.1 "	1.0 "
7th	Sup. . .		1.3 "	.8 "	1.1 "	1.4 "

The greatest disproportion occurs between the inferior surface of the composite piece and the superior of the 6th on the left side, and here presumably the greatest movement took place. It is noteworthy also that the articulations between the axis and the composite piece on the right and between the 6th and 7th on the left are partly horizontal, the latter more so. The question of the mechanism of the adaptation of the vertebræ to the restricted movements is not further entered into.

The THORACIC VERTEBRÆ do not require much detailed description. There is still some lipping of the bodies of the 1st and 2nd, and ankylosis of the bodies of the 4th and 5th; they are not united behind, and the line of union is elsewhere indicated by a ridge. The 9th has two incomplete

facets on each side of the body, the 10th one incomplete facet, while the 11th has a complete facet nearly on the pedicle. The 12th has a complete facet on the pedicle and none on the transverse process, and the 13th is similar in all respects to an ordinary 12th. It has three tubercles on the transverse process, the superior articular processes look mainly backwards, and the lower, though lost, must have been turned outwards, as the superior of the next vertebra look inwards. It will be seen that the 10th, 11th, 12th, and 13th vertebræ correspond to the ordinary 9th, 10th, 11th, and 12th.

**RIBS.**—Both *1st ribs* articulate with the 1st thoracic body, and to a considerable extent with the intervertebral disc above it, the left just failing to reach the body of the 7th cervical. The left is a little larger in nearly every respect than the right, as the following table of measurements shows:—

	Right.	Left.
Greatest length (tubercle-tip) . . . . .	7·3 cm.	8·4 cm.
Least „ (head-tip) . . . . .	5·8 „	6·3 „
Inner border . . . . .	8·5 „	9·4 „
Outer border (omitting tubercle) . . . . .	11·1 „	12·5 „
Breadth:		
Tip . . . . .	1·6 „	1·7 „
Tubercle (greatest) . . . . .	1·9 „	1·9 „
Neck (least) . . . . .	·8 „	·8 „
Subclavian groove . . . . .	1·7 „	1·6 „

The subclavian groove is distinctly divided into two portions on each side. In the posterior lay on the right side the 1st and 2nd thoracic, on the left the 1st thoracic contribution to the brachial plexus. The inner border of the rib is rounded opposite the posterior part of the groove, and nearly sharp opposite the anterior part in each rib. The anterior part of the edge is distinctly sharper on the right side; the posterior part of the edge is more rounded, and the posterior part of the groove a trifle more distinct on the *left*. It will be noted also that, although the left rib is in all other respects larger than the right, it is slightly narrower at the subclavian groove.

Ribs 2-8 right and 2-10 left are incomplete. The 5th pair articulate with the fused bodies of the 4th and 5th vertebræ; the 10th pair with the bodies of the 9th ( $\frac{1}{2}$ ) and 10th ( $\frac{2}{3}$ ) and the intervening disc; the 11th pair with the 11th vertebra and very slightly with the disc above; and the tubercle articulates with the transverse process. The 12th and 13th articulate with facets on the pedicles of their respective vertebræ and not with the transverse processes.



The following are the measurements of the last three ribs:—

	Right.	Left.
11th . . .	22·8 cm.	22·5 cm.
12th . . .	18·0 „	17·5 „
13th . . .	4·8 „	5·2 „

The sternum was unfortunately not preserved.

MUSCLES.—There was a well-developed *psaos minor* on each side attached to the 13th thoracic and 1st lumbar bodies. The *quadratus lumborum* was attached to the body of the 12th thoracic, and to the 12th and 13th ribs. The diaphragm was not attached on either side to the 13th rib, the costal fibres ending on both sides by blending with the *transversalis tendon* half an inch medial to the tip of the 12th rib. There was no “*ligamentum arcuatum externum*” on either side, and no well-defined “*ligamentum arcuatum internum*,” as the line of origin of the *psaos minor* from the 1st lumbar and 13th thoracic bodies was also the line of origin of the lateral part of the *crus* of the diaphragm. On the right side a fairly large hiatus was left between the attachment to the 12th rib and to the outer border of the *psaos*, but it was subdivided vertically by a narrow muscular band blending with the *transversalis tendon*; on the left side a similar hiatus was partially closed by muscular fibres arching transversely across from the 12th rib to blend with the lateral part of the *crus* over the *psaos*.

LUMBAR (fig. 6).—All the laminæ and some of the articular processes are lost. The left transverse process of the 1st has a thickening transverse to its length extending right across in front and over the lower half behind, and projecting above and below as a small knob. The 2nd has lost the left half of its neural arch. The 3rd right transverse process shows a thickening similar to that on the 1st left. The transverse processes of the 4th are smaller than those of the 3rd and distinctly triangular, the left being the narrower and more pointed; they are attached to the pedicles only. The transverse processes of the 5th, stout and pyramidal, spring from the side of the body as well as from the pedicle; their superior surfaces are on a level with the posterior part of the crest of the ilium.

*Length of Lumbar Transverse Processes.*

	Right.	Left.
1st . . . . .	2·0 cm.	2·0 cm.
2nd . . . . .	2·6 „	...
3rd . . . . .	2·7 „	2·65 „
4th . . . . .	2·5 „	2·0 „
5th . . . . .	1·7 „	1·5 „

*Bitransverse Measurements.*

1st	.	.	.	.	.	7.8 cm.
2nd	.	.	.	.	.	...
3rd	.	.	.	.	.	9.6 "
4th	.	.	.	.	.	9.1 "
5th	.	.	.	.	.	8.7 "



FIG. 6.—Lumbar transverse processes.

It is to be noted that the relative size and shape of the lumbar transverse processes are similar to those found in an ordinary set of five lumbar vertebræ, viz., a steady increase in length to the 3rd, a shorter and characteristically upturned 4th, and the highly characteristic 5th attached to both pedicle and body.

SACRUM 5, COCCYX 4.—The sacrum, unfortunately, was broken through the middle and a small portion lost, but the amount of damage done was not sufficient to prevent a satisfactory reconstruction: it consists of five pieces and requires no special remark. The four pieces of the coccyx are

fused together, and the whole ankylosed to the sacrum at an angle convex forward. The following are the transverse measurements of the coccygeal segments: 1st, 3 cm.; 2nd, 1·8 cm.; 3rd, 1 cm.; 4th, ·4 cm. The 1st has small transverse processes grooved in front but no trace of cornua. The 2nd has rudiments of transverse processes, and the 3rd and 4th are rounded, the 4th being very small.

**CURVATURES OF COLUMN AS A WHOLE** (fig. 1).—In the cervical region there is a well-marked convexity to the left, greatest opposite the point



FIG. 7 —Photograph of ventral aspect of cervical spinal cord.

where the half-body is missing on the right side. In the thoracic there is a slight convexity to the right, with a diminution opposite the fused 4th and 5th bodies, and in the lumbar a moderate convexity again to the left, greatest opposite the disc between the 2nd and 3rd bodies.

**SPINAL CORD** (figs. 7 and 8).—A portion of the spinal cord, extending from the 2nd to the 8th cervical segment, has fortunately been preserved. On opening the dura and arachnoid it was seen to have a slight curvature convex to the left, corresponding to the curvature of that part of the canal in which it lay. The 4th and 5th nerve roots of the left convex side are arranged in the ordinary manner in their relation to the cord itself, the

ligamentum denticulatum, and the dura mater. The rootlets on the concave right side, corresponding to the 4th and 5th left, converge to pierce the dura mater at a single point to form what is the 4th nerve in series on that side. The area of origin of the rootlets of this nerve is slightly overlapped both above and below by the area of origin of the 4th and 5th left combined. There is one dentation of the ligamentum denticulatum fewer on the right side, the upper rootlets of the nerve running downwards very



FIG. 8.—Photograph of dorsal aspect of cervical spinal cord.

obliquely to pass below the dentation which, corresponding to two on the left, is situated almost exactly opposite the interval between them, and therefore nearly opposite the point at which the left 4th nerve roots pierce the dura. The lower rootlets run nearly horizontally. As stated in the introduction, the roots are broken just at the point of piercing the dura, but their general course, the position of the opening in the dura, and their relation to the ligamentum denticulatum are perfectly clear.



*Areas of Origin of Nerve Roots.*

		Ventral.	Dorsal.
"4th"	Right . . . . .	1.8 cm.	2.1 cm.
4th and 5th	Left . . . . .	2.2 "	2.4 "

*Ligamentum Denticulatum. Interval between Points.*

	Left.		Right.
3rd and 4th . . .	1.5 cm.	3rd and 4th . . .	2.0 cm.
4th and 5th . . .	1.1 "		
5th and 6th . . .	1.0 "	4th and 5th . . .	1.4 "
	<hr/> 3.6 cm.		<hr/> 3.4 cm.

The origin of the spinal accessory nerve appears to extend to about the same point on both sides: on the left to the interval between the origins of the 4th and 5th dorsal roots; on the right to the middle of the origin of the "4th" dorsal root.

NERVES.—The record of the dissection of the nerves is not as complete as might be wished, but the following essential points were noted. The brachial plexus, "normal" on the left side, was "postfixed" on the right. It was formed on the left side by the 5th, 6th, 7th, and 8th cervical, and 1st thoracic, with a small communication from the 2nd thoracic; the phrenic nerve arose mainly from the 4th cervical. On the right side the plexus was formed—taking the cervical nerves in numerical order as found—by the 5th, 6th, and 7th cervical, 1st and 2nd thoracic, the phrenic arising mainly from the 4th. But, remembering that the 4th right nerve represents two nerves, and renumbering the others with that fact in view, the plexus really arises from the 6th, 7th, and 8th cervical, 1st and 2nd thoracic, and the phrenic nerve arises mainly from the "4th," the doubtful nerve.

There is thus an inequality of one nerve in the formation of the brachial plexus on the two sides, but this inequality does not affect the formation of the other plexuses.

There are thirteen pairs of thoracic nerves, and, taking the 13th as equal to the ordinary 12th, the arrangement caudal to this point is in the main quite usual. The lumbo-sacral cord was formed on each side by the 4th and 5th lumbar nerves, the 25th and 26th spinal nerves, allowing again for the absence of the 3rd right cervical. The obturator and femoral nerves were both formed on each side from the 2nd, 3rd, and 4th, while on both sides the genito-femoral was traced to the 1st only, and the lateral cutaneous to the 1st and 2nd.

## SIMILAR DEFICIENCIES PREVIOUSLY DESCRIBED.

The deficiency of half a vertebra has not been often recorded, and never before with the corresponding portion of the spinal cord, or indeed with any mention of the associated nerves at all.

Rokitansky appears to have been the first to record deficiency of a half vertebra, in the 3rd volume of his *Pathological Anatomy*, 1842-46: yet he writes as if it were a well-recognised cause of scoliosis. "An allied deficiency, in which one or more vertebrae or half vertebrae are of small size or altogether absent, sometimes co-exists with other malformations," but "sometimes occurs in persons who are otherwise naturally formed." "It is interesting to observe in persons who are in no other way deformed, how the want of one-half of a vertebra, in the same manner as a half too much, produces congenital lateral curvature." "Excess of development is exemplified in the presence of an unusual number of whole or half vertebrae. . . . An excess of one or more halves of vertebrae occasions a congenital lateral curvature, in the same manner as a deficiency of halves of vertebrae; and it constitutes a most remarkable instance of scoliosis, of which I shall treat more at large hereafter." "Sometimes the curvature results from deficiency of the lateral half of a vertebra, or from unequal development of the two halves of the column, or from the presence of one or more half vertebrae too many."

He described three cases. (1) In the first (C7T11½L4SC—), a tailor aged 70, the lower six cervicals are united into one piece: the right half of the 9th thoracic is wanting, and the left half united to the 8th. The last lumbar is sacralised. (2) The second is a kyphotic spine occurring in a female, aged 55, as a result of the 12th thoracic vertebra consisting of two divided lateral halves: the triangular rudiments lie between the 11th thoracic and the 1st lumbar, points inwards, and are united to the latter. (3) The third is the most remarkable—compound scoliosis occasioned by the presence of supernumerary lateral halves of vertebrae which "compensate" each other. The spine, of a female aged 46, is in the Museum at Vienna, and was described by Rokitansky as "a very old preparation." There is a half vertebra between the 5th and 6th thoracic: the 7th thoracic and the 1st sacral are double on the left side, the 1st lumbar on the right. The laminae terminate in a row of asymmetrical spines from the 1st thoracic to the 2nd lumbar. There are thus four half-arches too many; and the formula apparently is C7T13L6S5C—, there being thirteen pairs of thoracic ribs and a pair of cervical ribs. There is ankylosis between the odd half-arches and the bones next them, between several of the bodies,

especially in the concavity of the curvature, and also between the 2nd and 3rd cervical vertebræ.

Humphry, although he had himself examined many foetal spines with great care and had never found anything but a single nucleus, collected evidence in 1858 to show that the body of a vertebra may sometimes develop from a double nucleus. He mentions a number of instances of double vertebral bodies which he had seen in museums, occurring in spina bifida and other malformations; quotes two of Rokitsansky's cases; and gives in addition two others. One is deficiency of the left half of the 11th thoracic, recorded by Otto. In the other, figured by Sandifort, there is absence of half of the bodies of the 7th cervical, 9th and 11th thoracic; "the remaining halves are wedge-shaped, and some of the bodies lower down have two distinct nuclei, one on either side."

Dr James Goodhart recorded in 1875 several cases of malformation associated with extreme deficiency of vertebral segments. (1) In the first of these, a male aged 64, there is fusion from the 7th cervical to the 4th thoracic, and "the left halves are in a somewhat rudimentary condition." The whole of the body of the 1st lumbar, the left half of the 12th thoracic, and the right half of the 2nd lumbar are wanting, in each case the transverse processes being represented; the two halves of the 4th lumbar body are not joined in the middle line. There is a 13th rib on the left side, the 12th being "unusually long" on both sides. (2) The second is a hydrocephalic male foetus with only  $4\frac{1}{2}$  cervical bodies, the odd half being the lowest. Each body consists of two rounded masses distinct from each other as far as the 9th thoracic; the laminae are widely separated. (3) The third, an adult column, again shows distinct development of the bodies from two centres and the difficulties that may arise in interpretation through cross ankylosis of these centres. Goodhart also mentions two other cases, both foetal, in one of which there was "an odd half vertebra developed in excess," in the other "fusion of superimposed halves of two vertebræ on the left side about the 8th dorsal," and he comes to the conclusion that "cases of asymmetry are due to original malformation of the bodies in the direction of bilobed or double nucleus, and subsequent unequal growth."

Struthers in his description of vertebral variations in 1875 does not mention absence of half a vertebra.

Willett and Walsham in 1880 described a case, in a woman aged 31, of sharp lateral curvature, with convexity to the left in the upper thoracic region, due to the absence of  $4\frac{1}{2}$  thoracic vertebræ, including the right half of the 3rd, the 4th left and 5th right ribs being also wanting. The authors say that "the absence of half a vertebra has generally been ascribed to



defects in the process of ossification," and suggest that it must be due to changes occurring at an earlier period of development, "probably at the time of the primary segmentation."

Sir W. Turner recorded in 1886 a vertebral column in which the 10th thoracic body is represented by two wedge-shaped pieces, each with a facet for the 10th rib and continuous with a pedicle, a condition similar to one of Rokitansky's cases.

Professor Reid in 1887 figured and described a specimen to which no history is attached. The right half of a vertebra is wedged in between the 8th and 9th complete thoracic vertebræ. The body, the superior articular processes, and the well-developed lamina and half-spine are fused with the corresponding parts of the 8th, the inferior articular processes with the 9th. From the fact that the specimen is isolated it is impossible to say whether this half vertebra is additional, or the remaining half of a deficient vertebra. There is a well-marked intervertebral foramen both above and below it.

Professor Paterson and Dr Lovegrove recorded in 1898 a foetal column in which the left half of the 7th thoracic body is wanting; and another in which, the bodies being normal, there is a mixing of the laminæ.

Professor Dwight, in the introduction to his account of forty-five anomalous spines in 1901, mentions "a lateral half of a sacrum which probably had an extra half vertebra on one side": and refers to the python,<sup>1</sup> discussed also by Baur and by Bateson, and figured by the latter, in which the 166th and the 185th vertebræ are each double on one side, with two transverse processes and two ribs.

Since the introduction of X-rays a number of cases of congenital scoliosis have been ascribed to absence of half a vertebra.

Mouchet in 1898 appears to have been the first to record such a diagnosis, in a girl aged 2, in whom he found "an extra half vertebra between the 1st and 2nd lumbar." The following year he recorded "an extra half" in exactly the same position in an anencephalic female foetus.

He was followed by Codivilla, who in 1901 described "an extra half between the 2nd and 3rd lumbar" in a girl aged 11. In the same year Fleury wrote a thesis on another case in which it was afterwards shown

<sup>1</sup> This python is in the Royal College of Surgeons of England Museum, and I am indebted to Professor Keith for information regarding it. Professor Keith also pointed out to me that the vertebral column here described exhibits irregularities very similar to those that occur in congenital elevation of the scapula (Sprengel's shoulder). Particular attention was, however, paid to this possibility by Professor Jamieson when the abnormalities were discovered, as he had recently seen a case of the condition clinically; there was no suggestion that the scapulae were displaced nor any abnormality of them. We discovered later that the man had been in the army, so that the shoulders must have appeared fairly regular during life.



by Mouchet and Broca that the left half of the 12th thoracic was absent.

In 1909 Mr Duncan Fitzwilliams, from whose paper the particulars of these cases of congenital scoliosis diagnosed by X-rays have been obtained, called attention to the subject by the publication of his case in a girl aged 16 months. The mother had noticed the deformity since birth; neither rickets nor spinal caries was present, and an X-ray photograph revealed a wedge-shaped vertebra between the last thoracic and the 1st lumbar. There were apparently six lumbar vertebrae. In the following year Dr Frederick Langmead recorded a similar case in a girl of 10 months. Since then a number of cases have been recorded, but in all the evidence has consisted of the X-ray picture only; in none, so far as I am aware, has there been any subsequent post-mortem examination, and consequently no accurate account of the condition of the bones, and none of the spinal cord and nerves.

## PART II.

### ABSENCE OF HALF A VERTEBRA.

The actual numerical position of the odd half vertebra had to be determined, and although, as already mentioned, there was at first some little doubt, it became quite clear that it belonged to the 3rd. Next the question arises whether it is the remaining half of a deficient vertebra, or an additional half intercalated between the 2nd and 3rd, a question which insists on a definite answer when we find that there are thirteen thoracic vertebrae with normal lumbar and sacro-coccygeal regions. But if we look upon the odd half as an addition, then we have only six cervical vertebrae, or else the best developed pair of cervical ribs that could be imagined, so simulating the ordinary 1st ribs in every respect as to be indistinguishable from them. These ribs must, in fact, be considered ordinary 1st ribs unless we wish to ascribe a penetrating and absolute individuality to every member of the ordinary series of vertebrae. Had the 3rd cervical vertebra been completely instead of partly absent, the column would then have been an example of absence of a cervical vertebra and presence of an additional thoracic, *i.e.* the formula would in reality have been C6D13L5S5C4, without any question of the mere transference of the lowest cervical to the thoracic through the development of its costal element, a condition which Dwight hesitated to describe. Further, the conditions present in the portion of spinal cord preserved show that we are dealing with something that affects more than the bones, and it is clear therefore that presence or absence of half a vertebra is not a sufficient *explanation*.

Dwight defines intercalation as "the presence of an extra vertebra between two *particular* vertebræ," and Birmingham pointed out some years before that if a vertebra is intercalated there should be no nerve to one vertebra. In most of the discussions on intercalation this fact has not been properly appreciated, and the distinction between intercalation of a vertebra or portion of a vertebra and intercalation of a segment or portion of a segment has not been properly drawn.

We are probably dealing then with  $6\frac{1}{2}$  cervical segments, and we have to consider how the loss of half a segment has occurred. Should we consider the bone alone we might simply say "defect of ossification," for there is clear evidence that the vertebral bodies are sometimes ossified from two centres; but remembering the condition of the spinal cord and the nerves, the main interest lies in these. Now, from the areas corresponding on the right side to the areas of origin of the 4th and 5th left nerves we have arising a single nerve, and the question then is whether the two have run together or if one is absent. If a nerve is absent, then it is clear that this cannot have been brought about by a defect of ossification, rather the deficiency of the bone will depend on the early fault of segmentation; whereas if two nerves have run together it is possible that this may have been caused by the defect of ossification on the converse of Birmingham's principle that if there is *recalculation* of a vertebra there should be two nerves to one vertebra. It is, of course, possible that if two nerves were run together the resulting nerve might be smaller than the sum of the two original components, and also that, if a nerve be absent, the neighbouring nerves might be larger, so that the size of the nerve in question might be very nearly the same on either hypothesis.

As a matter of fact, the surface areas of origin, ventral and dorsal, of the "4th" right are less than the respective combined areas of the 4th and 5th left, and the number of distinct rootlets is: "4th" ventral, 7: dorsal, 9: against 4th and 5th ventral, 14: dorsal, 13. It is not likely either that the 2nd thoracic nerve would contribute so much to the brachial plexus on the right side only were the 4th and 5th cervical nerves merely run together, nor would one expect the very definite single point of exit from the dura mater for all the fibres, nor the regular arrangement of the ligamentum denticulatum. On the suggestion of Professor Robinson an attempt was made to count the fibres in the roots of the nerves in question, and although the results are far from having any absolute value, yet they contain in themselves evidence that they are at least *comparatively* trustworthy.<sup>1</sup>

<sup>1</sup> As the roots were much shrunken, it was impossible, after treating with osmic acid, to count any of the smaller fibres; hence the numbers arrived at are much below what is said to be the average, and this is particularly the case in the dorsal roots.

		Ventral.	Dorsal.
Right "4th"	. . . . .	2390	4760
Left 4th	. . . . .	2940	4430
.. 5th	. . . . .	4250	5470
		} 3595      } 4950	

The figures of the left 4th and 5th dorsal are in each case greater than the figures of the ventral root, and the counts of the two nerves are sufficiently near to justify a comparison with the right "4th." The



FIG. 9.—Photograph of outline drawings of serial sections of cervical spinal cord numbered consecutively; the level of the section is also indicated (see fig. 10). The typical series on the right of the figure are after Bruce's Topographical Atlas of the Spinal Cord.

figure for both ventral and dorsal roots of this nerve will be seen to be less than the average of the left nerves, a result which is in favour of the right nerve being single.

The spinal cord was also sectioned with a view to determining the different segmental levels, to find out if the irregularity of the nerves was paralleled in the cord; and if so, whether additional evidence could thus be obtained of the identity of the missing segment.

To preserve in series the parts into which the portion of cord was cut, the method recommended by Dr Edwin Bramwell was adopted, threading them on a horse hair passed through the left side of each part from above. Serial sections  $16\mu$  were cut, and stained deeply with hæmatoxylin. Outline drawings by projection were then made of every 10th section in

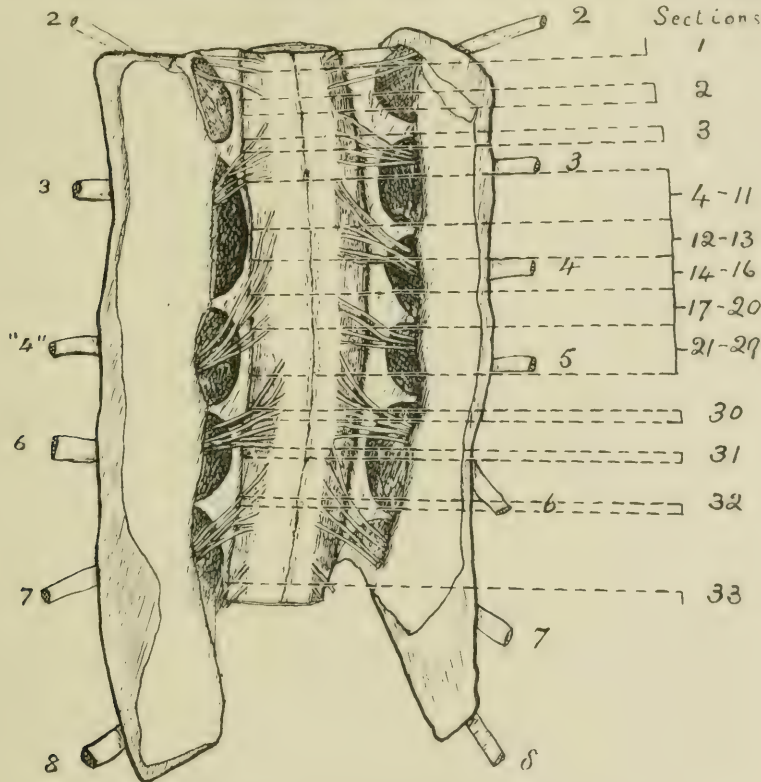


FIG. 10.—Ventral aspect of cervical spinal cord, with key to fig. 9.

the doubtful region, and above and below this of sections from the middle of each segment and the intervals between them. Fig. 9 is from a photograph of the drawings mounted in series: similar outlines (on a different scale) from the late Dr Alex. Bruce's *Atlas of the Spinal Cord* are shown for comparison. It should be noted that the cord was somewhat flattened antero-posteriorly; and that each section is looked at from above, so that the left side of the cord is on the left hand of the reader as indicated by the lettering in the figure. Fig. 10 is a key to the position of the sections.

The sections are numbered consecutively, and it will be observed that



the two sides are fairly symmetrical except from the 3rd to at least the 19th section. Looking at the left side of the sections first, it will be seen that they correspond closely to Bruce's types; the typical appearance of the 4th is best seen in sections 9 and 10, of the 5th in section 19; and sections 30, 32, and 33 clearly correspond to the 6th, 7th, and upper part of the 8th. On the right side the same sections, 30, 32, and 33, are again clearly 6th, 7th, and upper part of the 8th. The characteristic outlines of the ventral horns of the 6th, anvil-shaped, and of the 7th, rhomboidal, are clearly seen on both sides.

Sections 12 to 20, which on the left side are from segments 4 and 5 and intervening portion, are on the right side through the portion of cord from which the doubtful nerve arises, and it is suggested that the outlines of these on the right are much more like the 5th all the way through, the characteristic outline of the ventral horn with double concavity and prominent antero-lateral and postero-lateral angles being well seen even in section 12. If, now, the right side of the sections be traced up from No. 11, which is just at the upper end of the origin of the doubtful nerve through the transition from that of the 3rd segment to No. 3, the double concavity can be traced at least as far as No. 8, and there is no appearance of the characteristically broadened 4th with rounded angles. The section through the 3rd segment (No. 3) is not very like the corresponding typical section on either side: the interpretation of the sections from 3 to 11 is difficult: but there can be no doubt that from 12th to 20th the right side is strongly suggestive of 5th all the way, while the left is definitely 4th above and 5th below.

A striking feature is the relative smallness of the right grey crescent from the 3rd to the 18th sections, and it is suggested that the study of these sections leads to the conclusion that the right half of the portion of the cord represented by sections 12 to 20 is one segment, and that segment the 5th, and that the 4th right segment is not represented.

#### NUMERICAL VARIATION IN THE CERVICAL REGION.

The cervical is a relatively stable region: apart from the subtraction or addition of a vertebra by greater or less rib development the number of its segments is remarkably constant.

The presence of eight cervical vertebræ followed by a vertebra bearing a pair of ribs with undoubted 1st thoracic characters is a rare condition. Dr Barclay Smith recorded a case in 1911, and mentioned a few others: but thinks that "in some of these instances the cervical excess is to be accounted for by the 1st thoracic vertebra evincing cervical characteristics,

the 1st rib being rudimentary." The undoubted cases appear to be those recorded by Sir W. Arbuthnot Lane, Leboucq (two cases), and Dr Barclay Smith.

The opposite condition—six cervical vertebræ followed by a vertebra bearing a pair of ribs with undoubted 1st thoracic characters—is even more rare. The only recorded case appears to be that of Dwight (13), and he expresses doubts whether the ribs are to be considered cervical or thoracic. Leboucq stated that in his belief the addition of a vertebra in both his cases is due to an intercalation after the axis, and in one of them thought this to be the result of reduplication of the axis. Dwight discusses this point, and comes to the conclusion that there is no reason to see anything more than fusion. "Leboucq," he goes on, "asks whether we are to consider his finding twice an intercalated vertebra at this place anything more than a simple coincidence. He thinks that the place below the axis is a critical one in the cervical column, and that the 3rd vertebra is exposed to more variations than the others. He cites Murie to the effect that the reduction of the cervical vertebræ to six in the manus arises from an almost complete regression of the 3rd."

In both Leboucq's cases, further, the axis and the 3rd vertebra were fused together, a condition also present in the case of eight true cervicals described by Dr Barclay Smith. Nor is this synostosis of axis and 3rd confined to the cases of additional cervical; it has also been described in cervical regions with the normal number of vertebræ by Rokitansky, Goodhart, Arbuthnot Lane, Dukes and Owen, and by Dwight, who has seen it four times. Thus we have eleven cases altogether of fusion at this point, and the evidence is strong that it is a critical point. It was thought at first, when the odd half vertebra was believed to be the 3rd, that the present instance rendered that evidence stronger. The odd half, however, proved to be 4th, and the 3rd is fused not to the axis but into a composite mass with the succeeding one and a half vertebræ. This fusion can hardly be taken as part of the evidence of the inherent instability of the region, in view of the more obvious suggestion that it is a reaction to the acute curvature produced by the absence of the half vertebra. Whether the fusion was congenital or developed later hardly affects the argument: it is accompanied by osteoarthritic disease, which also may owe its origin to the extra stress involved by the curvature, but is in any case common enough in the neck of old subjects.

The mixing and fusing of the laminae is not in itself an essential feature, as it occurs in cervical regions with the ordinary number of vertebræ and no fusion of the bodies. Such cases have been recorded among others by Paterson and Lovegrove in the foetus, and Dwight in the adult.

FIRST RIBS.—It has already been pointed out that the 1st ribs are typical in every respect (fig. 2). A glance at the table of measurements will reveal some interesting points when taken in conjunction with the condition of the nerves. It will be noted that the left is larger than the right save in the one point, that it is narrower at the subclavian groove. The posterior part of the groove is also more distinct and its inner edge rounded, and yet it is not on this side but on the other that the brachial plexus receives the large contribution from the 2nd thoracic nerve. That is to say that the rib on the side with the postfixed plexus, though slightly smaller on the whole than the other, is not so distinctly marked by the arching over it of large contributions from the 1st and 2nd thoracic nerves to the brachial plexus as the other rib is by the contribution from the 1st thoracic alone. This observation is in opposition to a far-reaching application of the views of Dr Wood Jones on the influence of the nerves in the moulding of these ribs, though the fact that the lowest cord of the plexus invariably lies in the posterior part of the groove may be taken as established. Dr Low has recorded the opposite condition, a rudimentary 1st rib on one side with a normal plexus on both; and Professor Wingate Todd has described a case in which a cervical rib, 8 cm. long, was present on each side and the plexus normally constituted on both. The slightly smaller size of the right rib *may* of course be associated with the postfixed plexus, but it is to be remembered that it is only *very* slightly smaller, and that the other abnormal conditions present are quite sufficient to account for the difference, which is indeed well within the range of differences between the 1st pair of ribs under ordinary circumstances.

#### FUSION OF THE BODIES OF THE THIRD AND FOURTH THORACIC (figs. 2 and 3).

The question of the origin of the synostosis at this point is of some interest. Is it purely accidental, is it a result of the mechanical conditions produced by the cervical lateral curvature, or has it some special significance in view of the fact that we have here an additional true thoracic vertebra? As for the mechanical suggestion, there is certainly a diminution of the thoracic lateral curvature at this point, but this is more likely a result than a cause, as such a diminution is not at all usual in scoliosis. There is, on the other hand, no evidence for the view that there is some special reason for this isolated synostosis. It is possible that there may have been reduplication of the 3rd thoracic, as Leboucq thought there was of the axis in one of his cases, but a number of measurements of the series of thoracic vertebræ compared with the normal measurements given by



Anderson and by Dwight do not indicate any unusual feature at this point. Measurements are, in any case, of little individual value, since there is no reason to suppose that the sizes of the different vertebrae are not entirely due to adaptation to the function of the column as a whole. Dwight indeed has shown in one case (C7T11L5S5C4) that the eleven thoracic vertebrae exceeded the normal twelve in length by 16 mm. In the column under discussion the average of the front and back measurements of the thirteen thoracic exceeds that of the normal twelve (as given by Dwight) by 3 cm., which is greater than the individual height of any one vertebra. Therefore, although it is true that in every case of abnormality of the column an effort appears to be made to discount the initial deficiency or addition of a part by a functional adaptation of the whole, yet this adaptation need not always have the thoroughly structural effect suggested by Dwight.

There is no evidence that there is an addition of a thoracic vertebra at any one point, but in view of the facts that there is undoubted absence of half a vertebra, and that, had the other half of the same vertebra also been suppressed, there would have been no evidence left that the vertebra had disappeared *at that point*, it is quite reasonable to suppose that addition or suppression may take place at a particular point, *i.e.* that "intercalation" and "excalation" are possibilities. We cannot, however, say more in this case than that there are thirteen instead of twelve vertebrae without ascribing individuality to the extra member of the series.

#### THE THIRTEENTH PAIR OF RIBS.

It has been noted by Dwight that where the last pair of ribs is very short the penultimates are much longer than usual. These ribs are an instance, as the measurements already given show: it will be noted that the longer 13th is associated with the shorter 12th.

#### LUMBAR, SACRAL, AND COCCYGEAL REGIONS.

The only difficulty in the sacral and coccygeal regions arose through the destruction of a small portion of the sacrum. As a result, there is a little doubt whether there are four or five coccygeal segments, a point which is of little importance. Of much more importance is the fact that the lumbar and sacral regions taken together are remarkably normal. There is no striking evidence, such as one often finds when thirteen ribs are associated with five separate lumbar vertebrae, that the 5th lumbar is really derived from the sacrum. The five lumbar vertebrae and the region



round the lumbo-sacral articulation are quite ordinary in appearance. The transverse processes particularly give one the impression that the vertebræ to which they belong are five ordinary lumbar (fig. 6).

For the sake of comparison, outlines of the lumbar transverse processes of four spines with different formulæ are given.<sup>1</sup> It is at the least unlikely that if the number of lumbar vertebræ has been made up to five by the addition of a segment from the sacrum, the five trans-

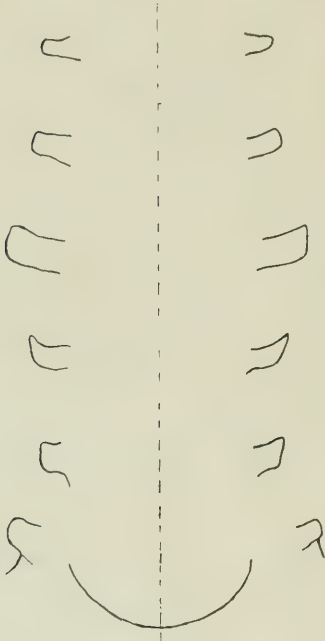


FIG. 11.—Lumbar transverse processes, spine A. C7T12L5S6Co4.

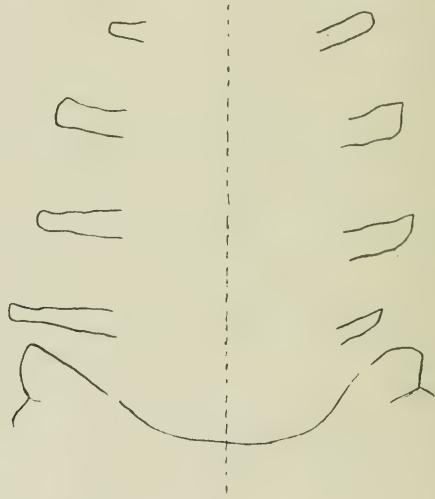


FIG. 12.—Lumbar transverse processes, spine B. C—T12L4S6Co—.

verse processes should exhibit exactly the characteristics of the ordinary five, and that the 4th in particular should not indicate that it represents the ordinary 5th.

SPINE "A," C7T12L5S6Co4 (fig. 11).—The 1st piece of the sacrum is partially separated, the transverse processes being indicated. There is a slight angle between the body and the rest of the sacrum, and the inferior articular processes are free. The lumbar transverse processes increase in length to the 3rd: the 4th are smaller and turned up; the 5th

<sup>1</sup> These spines are in the Anatomical Museum of the Leeds Medical School.

short and stumpy, and attached to the body as well as to the pedicle. The spread from tip to tip is as follows:—

1st	.	.	.	.	6	cm.
2nd	.	.	.	.	6·4	„ (estimated, as the tip of the right is broken).
3rd	.	.	.	.	7·8	„
4th	.	.	.	.	6·8	„
5th	.	.	.	.	6·4	„
1st sacral	.	.	.	.	8·1	„

SPINE “B” (fig. 12).—This spine (C—T12L4S6Co—) exhibits the opposite condition, the last lumbar being partially sacralised. There is a well-marked angle, the transverse processes are only partially fused, and the laminae and inferior articular processes are quite free.

The lumbar transverse processes increase in length to the 3rd; the 4th on the left side is small and triangular, but on the right is drawn out so as to be quite unusually long and thin. In spite of this, however, the spread of the 4th is not any greater than that of the 3rd pair. The transverse processes of the 1st sacral are clearly typical 5th lumbar. The spread is as follows:—

1st	.	.	.	.	.	6·8	cm.
2nd	.	.	.	.	.	9	„
3rd	.	.	.	.	.	9·8	„
4th	.	.	.	.	.	9·8	„
1st sacral	.	.	.	.	.	10·2	„

It should be noted that there is evidence of a cervical rib having been present on the left side.

SPINE “C” (fig. 13).—In this spine (C7T13L4S6Co—) the 1st lumbar vertebra has a pair of ribs, and there is very slight separation of the 1st sacral. The 1st lumbar transverse processes are turned down slightly, the 2nd are straight and longer, the 3rd are a trifle longer again, but markedly turned up, while the 4th, also turned up, are thick and pyramidal and attached partly to the body. The spread is as follows:—

1st	.	.	.	.	.	8·0	cm.
2nd	.	.	.	.	.	8·6	„
3rd	.	.	.	.	.	9·0	„
4th	.	.	.	.	.	8·5	„
1st sacral	.	.	.	.	.	8·7	„

SPINE “D” (fig. 14).—In this spine (C7T13L5S5Co—) the five lumbar vertebrae are quite ordinary in appearance: there is no evidence that the

5th has separated from the sacrum, the 1st sacral itself being in fact slightly detached behind. The transverse processes increase in the usual way in length to the 3rd; the 4th are typically short and triangular and upturned; the 5th pyramidal and attached to the body. This is another instance of a true additional thoracic vertebra, as it is extremely unlikely that the transverse processes would be so typically arranged were all the vertebræ moved one place upwards. By comparing the outlines of "D" with those of "C," where the 1st lumbar has been simply absorbed into the thoracic region, and those of "A," where there has been a partial move-

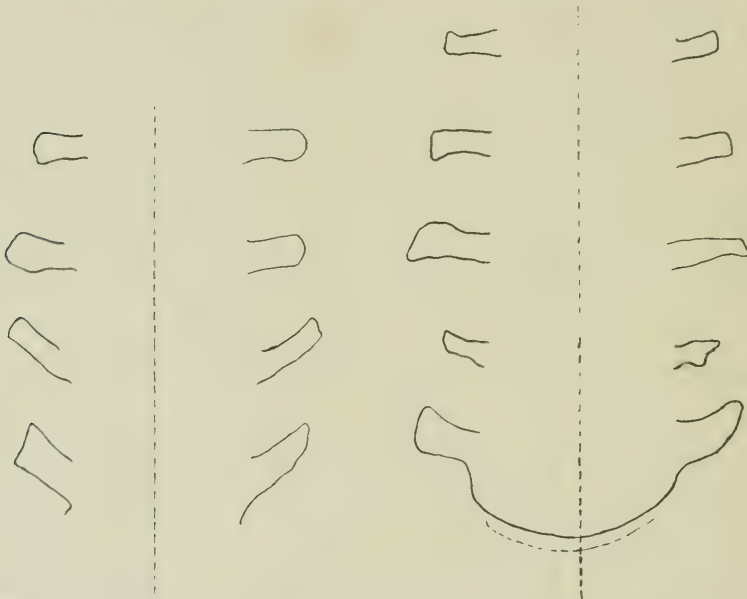


FIG. 13.—Lumbar transverse processes, spine C. C7T13L4S6Co—.

FIG. 14.—Lumbar transverse processes, spine D. C7T13L5S5Co—.

ment upwards but without the development of 13th ribs, this impression becomes very strong.

Lastly, compare "A" (fig. 11) and "B" (fig. 12), where the opposite conditions of lumbarisation of the 1st sacral and sacralisation of the 5th lumbar are exhibited, so that there is at least a whole vertebra length difference between the two, and yet the characteristics of the lumbar transverse processes are clear in both.

The question at once arises of the cause of the peculiar shapes of the lumbar transverse processes: and it may be suggested that as they depend upon the muscles attached to them, the shapes will vary with the relative

distances of the processes from the crest of the ilium and the last rib irrespective of the number of the vertebrae with which they are associated. There is certainly some truth in this, and it is not suggested that there are no such differences, only that there are indications which enable one to say, in the lumbar regions here figured at any rate, independent of the level in relation to the crest of the ilium or to the last rib, to which vertebrae the transverse processes should be assigned. There is therefore evidence that the shapes of the transverse processes of the lumbar vertebrae are not entirely due to the muscular attachments: that they have, in fact, a value of their own.

#### SURGICAL INTEREST.

This vertebral column has a considerable interest from a surgical and particularly diagnostic point of view. Of late years the general use of X-rays has resulted in a number of cases of scoliosis being diagnosed as due to congenital deficiency of half a vertebra, but this aspect of the subject is not entered into here beyond stating that none of the cases, so far as can be ascertained, have been verified post-mortem, and that in some it is doubtful if they are due to the cause stated.

The clinical history of the present case is interesting in that it is negative so far as the conditions described are concerned; he was twice in hospital during recent years, and nothing abnormal was noted about the neck on either occasion. It was further ascertained that he was in the army for a number of years, so that there can have been no marked deformity. For these details I am indebted to Dr James Allan, Medical Superintendent of the Leeds Union Infirmary.

#### SUMMARY.

The anomalies here described are the absence of half a vertebra in the cervical region and associated deficiency of spinal cord and nerve. The absent half vertebra must either be the 3rd or the 4th, and it is proved from the arrangement of the nerves to be the 4th. It is suggested that the bone condition is secondary to the nerve abnormality; and from the external appearance of the roots, and the relative number of fibres contained in them, that a single nerve on the right corresponds to two on the left; and from the appearance of transverse sections of the cord that the single nerve is the 5th. The general conclusion is that there has been an error of segmentation involving the suppression of half a segment in the cervical and the addition of a whole segment in the thoracic regions:



that the two are directly connected there is no evidence, but it is reasonable to suppose that they are the effects of the same general cause.

I am much indebted to Dr Leo Rowden, Honorary Radiologist to the Leeds General Infirmary, for X-ray photographs: and I have to express my thanks to Professor J. Kay Jamieson for permission to publish this account, and for much advice and help during the progress of the work which it has entailed.

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## APPENDICES EPIPLOICÆ AND PERICOLIC MEMBRANES. By

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APART from inflammation, adhesions found in the fœtus and young child are scarcely if at all less extensive than those found in the adult.

Practically all are developed whilst the parts are actively growing, and most obvious causes for their formation are the pressure exerted upon parts by the relatively enormous fetal pelvic colon; the anchoring of or traction exerted upon parts, pulling or pressing them together, by the genito-mesenteric fold of peritoneum; and the firm resistance against pressure of the large liver, between whose visceral surface and the intestines and parietal peritoneum peritoneal sheets are "caught" and pressed together and adhere to one another and (as, for example, in the case of the stomach) to the parietal peritoneum. In short, in the production of an adhesion in the fœtus there must be relative fixation as well as pressing together of peritoneal sheets.

(1) *The Genito-mesenteric Fold*.—This adheres to the colon in the fœtus shown in fig. 1. In this fœtus it is clearly indicated that the pelvic colon is a cause of peritoneal adhesions as well as intestinal distortions. The pressure which it had exerted had undoubtedly caused the ascending colon to be bent upon itself; and the cæcum (which would have overlapped the pelvic brim had the colon been straight) had in this way been carried upwards and lay behind the pelvic colon (which had to be pushed to the left to expose it). The pelvic colon (which formed a *compressed omega-shaped* loop) also lay in contact with the genito-mesenteric fold, the lower part of which it had pushed towards the right off the line of the testicular vessels. The fold thus displaced was moulded over the colon to form a distinct pocket in which the flexure was lodged. Moreover, the pressure had caused the fold to adhere to what was originally the posterior surface of the bowel (we have seen that in some cases it may also cause it to adhere to the ileum, appendix, and cæcum), so that the colic flexure was rendered permanent in this remarkable manner.

When the bowel was shelled from the pocket the fold was seen to be roughly J-shaped. Its parietal border at first descended upon the testicular vessels, and at a point 1·7 cm. from the internal abdominal ring (annulus

inguinalis abdominalis) arched outwards for 1.3 cm. over the right iliac fossa. Laterally the fold bounded a small fossa (see fig. 1).

C. H. Mayo (see *Surgery, Gynecology and Obstetrics*, March 1911) believed that Jackson's membrane was formed by the rotating cæcum burrowing its way down behind the parietal peritoneum. This "is about the only hypothesis by which we can explain that form of Jackson's membrane which encloses the cæcum and ascending colon as in a bag"



FIG. 1.—Fœtus No. 1, ♂, nine months old. The strip of white paper rests upon the ascending colon (indicated also by a needle), and its lower end lies in the outer part of the pocket formed by the genito-mesenteric fold of peritoneum. To expose completely the pocket and cæcum the compressed omega-shaped loop of pelvic colon has been pushed to the left.

(Eastman); and I have shown that the genito-mesenteric fold may actually be wrapped over the bowel (appendix, cæcum, colon).

(2) *The Great Omentum*.—In adult A (see fig. 2) the right part of the transverse colon is closely and firmly bound to the ascending colon by the great omentum, which crosses between and adheres to both parts of the bowel.

(3) *Appendices Epiploicæ*. (a) *In Relation to the Ascending Colon*.—I have already published a photograph of a strong pre-colic membrane  
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(present in an adult dissected at Cambridge, Lent, 1914), and have indicated that there could be little doubt that it was formed by an appendix epiploica.

In two of the twelve adults whose abdomens were dissected at Cambridge, May term, 1914, I found strong membranes lying in front of the ascending colon (see fig. 3); and narrower bands were present in several other specimens.

In adult B the membrane was especially strong and extensive (see fig. 3). It stretched from the cæcum (which was normally placed) upwards to the hepatic flexure, where it had no connexion with the great omentum. It passed from the parietal peritoneum (formerly ascending mesocolon) along

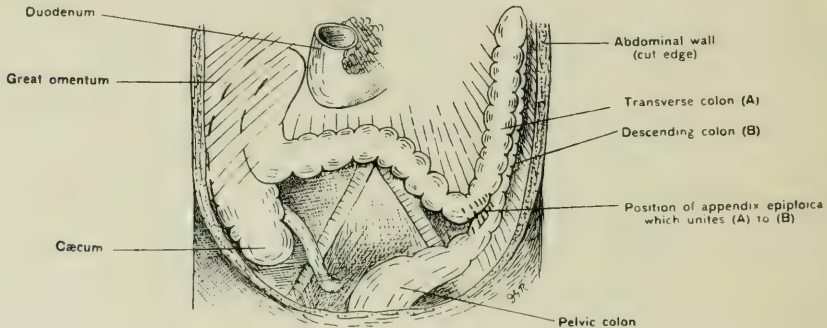


FIG. 2.—Adult A, ♀. The transverse colon is firmly bound to the ascending colon by the great omentum and to the iliac colon by an appendix epiploica.

the medial border of the bowel to end in a free margin which lay in contact with but did not adhere to the right lateral abdominal wall.

The anterior tænia coli was completely hidden, and at first it appeared almost as if the parietal peritoneum were continued from left to right across the anterior surface of the colon, whose outline was thus greatly obscured. The fold adhered loosely to the bowel, but did not bound a pre-colic fossa. It contained a considerable amount of fat distributed fairly uniformly, and arteries (derived from the right and ileo-colic vessels) visible to the naked eye and coursing at right angles to the long axis of the bowel.

The cæcum was 6.5 cm. broad. The ascending colon was telescopic in form, being subdivided into three distinct segments of different width. The first, or lowest, was not separated from the cæcum by any constriction, but at a point 4.5 cm. above this it became suddenly constricted as it passed into the second part. This extended upwards to about the middle of the ascending colon. It averaged 32 mm. in breadth, and a distinct constriction marked its passage into the third or highest part, which varied from 22 to 28 mm. in breadth.

At the hepatic flexure the bowel expanded quite abruptly, and the transverse colon was 5 cm. broad.

The cæcum and lowest part of the ascending colon do not tend to be constricted, and in this as in other cases were not dilated. The walls of



FIG. 3.—Adult B, ♂. A knife has been placed behind the free edge of the large appendix epiploica which prolongs the membrane in front of the ascending colon. Another knife lies in a foramen formed by the adhesion of a strong appendix epiploica to the transverse colon. The descending colon is also hidden behind a strong and extensive membrane. The strip of white paper indicates the position of the medial border of the descending colon. A small remnant of the genito-mesenteric fold of peritoneum is indicated by another knife. Between this fold and the cæcum the ileum is permanently curved.

the bowel were healthy. The muscular coats of the cæcum and transverse colon were practically normal in thickness. The muscular coat of the

ascending colon was three times as thick as that of the transverse colon. Both its layers were much thicker than normal.

The large free fold of peritoneum (see fig. 3) which prolongs the right border of the membrane is especially noteworthy, for it is undoubtedly an enormous appendix epiploica; and there can be no doubt that the whole membrane was formed by at least one gigantic appendix epiploica.

I have already published illustrations showing that these enormous folds do occur in relation to the ascending colon. A still larger fold (11·5 cm. long and (in most of its extent) 4·5 to 5 cm. high) was present in one of the twelve adults referred to. It was attached to the colon along an oblique line extending from a point to the left of the anterior tænia coli, one inch above the ileo-cæcal junction, upwards to the parietal peritoneum immediately to the right of the hepatic flexure.

In another of these adults a strong but relatively small appendix epiploica crossed the ascending colon to gain attachment to the lateral parietal peritoneum. It is quite common to find narrow bands formed in this way; but only in this adult did such a band produce a distinct constriction of the ascending colon.

(b) *In Relation to the Descending Colon.*—In adult B (see fig. 3) a strong and extensive membrane was also present coating the descending colon and completely obscuring the anterior tænia coli. It extended across the bowel from the parietal peritoneum (formerly mesocolon) immediately along the right border (indicated by a strip of white paper) of the colon. It adhered to the bowel, but its left border was prolonged by free processes of peritoneum (appendices epiploicæ) which came into contact with the lateral parietal peritoneum. It contained fat and blood-vessels which were visible microscopically and coursed transversely to the long axis of the bowel. It must have hampered the expansion of the (normally) narrow descending colon.

Although appendices epiploicæ are popularly regarded as being always "little" peritoneal processes or tags, it is very common to find enormous free folds of peritoneum (appendices epiploicæ) lying in front of the descending colon. They were present in four out of the five adults whose abdomens were dissected this term (Long Vacation, 1914). The measurements of the folds were as follows:—

	Length of Fold.	Maximum Height.
(1) . . . .	10 cm.	5 cm.
(2) . . . .	16 "	6 "
(3) . . . .	25 "	4 "
(4) . . . .	38 "	4·5 "



In (5) the only female dissected, the condition present is indicated in fig. 2.

In (4) the fold extended from the splenic flexure to the pelvic brim, and



FIG. 4.—Extensive pre-colic folds (appendices epiploicæ) removed from two adults. In the specimen to the left the colon between the splenic flexure and the pelvic brim has also been removed. It lies behind, and except at its upper part, is completely concealed by the fold between a part of which and the bowel a piece of white wax taper has been introduced. A small strip of parietal peritoneum (formerly mesocolon) has been removed with the bowel, and its endothelium is seen to be continuous with that of the fold. The appearance is very similar to that seen in adult B (fig. 3), where the fold has adhered to the colon. To the right is a still longer, but relatively narrow, appendix epiploica perforated by a foramen.

then along the pelvic colon for a considerable distance. In (2) half the fold lay along the pelvic colon. In (3) the fold extended from just below



the splenic flexure to the pelvic brim. In (1) the fold reached to the pelvic brim.

Lying in front of the descending colon, gigantic folds were also present in three of the twelve adults examined last term (May 1914). Two are shown in fig. 4. Although 25 cm. long, the fold seen to the right in the photograph did not exceed 3 cm. in height. It overlapped another large fold (12 cm. long and 3 cm. high).

In every case these folds arose from the peritoneum exactly along the inner border of the bowel, so that the endothelium of the fold was continuous with that of the parietal peritoneum (formerly ascending mesocolon) on the one hand and with that of the bowel on the other. As seen in fig. 4 it thus appeared as if the parietal peritoneum were prolonged over the colon. They all contained arteries (ultimate branches of the middle and left colic and sigmoid) visible macroscopically and lying at right angles to the long axis of the bowel. Had they become fused to the bowel a membrane exactly similar to that in adult B (see fig. 3) would have resulted.

There can be no doubt that this membrane was formed by a gigantic appendix epiploica which had become adherent to the bowel.

This adhesion may occur during foetal life. In a foetus 17 cm. long (see fig. 5) I found a membrane almost exactly similar to that present in adult B. It was an extensive sheet reaching from the upper end of the descending colon downwards to the ilio-pelvic colon. It had no connexion with the great omentum. It adhered to the bowel, but its left border, which came into contact with the lateral abdominal wall, was free and irregular, and here the membrane had all the characters of an ordinary foetal appendix epiploica. It contained blood-vessels which were visible to the naked eye and coursed outwards parallel to one another (see figure). Running longitudinally as well as transversely in the membrane were also some bundles of non-medullated nerve-fibres. The membrane was loosely attached to the colon by connective tissue containing some more deeply lying vessels and nerves, some of which could be seen entering the muscular coat of the bowel. It was undoubtedly formed by a very large appendix epiploica.

The largest appendices epiploicae which I have met with tend to spring from the colon nearest the line where the arteries first reach the bowel; and they tend to fuse to the ascending and descending colons from within outwards. In some cases the folds fuse down at some distance from their border of origin; in some cases simply at the border towards which the main arteries in the fold course.

We have seen that a pre-colic fossa and a parieto-colic fold of Jounnesco

may be formed in this way. A large and strong parieto-colic fold containing fat, and projecting from which were small appendices epiploicæ, was present in one of the adults dissected last term. It passed from the lateral part of the colon and bounded a deep retro-colic fossa. Without much doubt it had been formed in the way I have described in the fœtus.

In other cases a foramen, which might prove to be of surgical interest, results. Thus in adult B (see fig. 3) a strong appendix epiploica passed from one part to another of the transverse colon. It adhered most firmly

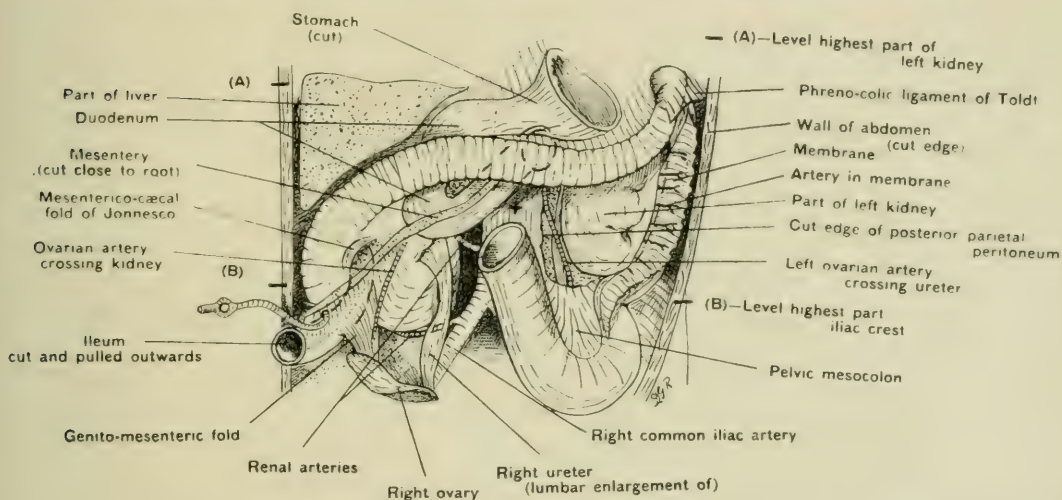


FIG. 5.—Fœtus No. II., ♀, 17 cm. long (vertex to coccyx). An extensive membrane is present in front of the descending colon. The renal ducts differ considerably in length; and the right kidney, extending from the upper border of the body of the first to the lower border of the body of the fifth lumbar vertebra, lies considerably below the left, which reaches from the upper part of the eleventh dorsal to the lower part of the third lumbar centrum (*cf.* (A), (A)). The lower part of its hilum is placed on the ventral surface of the kidney and looks directly forwards. Above the hilum passes on to the inner border of the kidney and looks inwards and forwards as in the adult. An accessory renal artery arises from the right common iliac artery and passes behind the ureter to enter the lower extremity of the right kidney. Above this two renal arteries enter the renal sinus, one at each extremity of the upper part of the hilum. They arise separately from the aorta, distinctly below the level of the normal left renal artery, and cross in front of the inferior vena cava. The lower artery, directed somewhat upwards, is retro-pelvic. The upper (horizontal) is pre-pelvic, with a strong retro-pelvic branch; and this disposition is perhaps interesting in association with the more equal development of the upper parts of the labia of the hilum (*cf.* A. H. Young and Peter Thompson, *Journal of Anatomy and Physiology*, vol. xxxviii. p. 1). The descending colon skirts the outer border of the left kidney; and its lower part curves inwards to intervene between the lower pole of the kidney and the iliac crest. (In another 17-cm. fetus the lower pole of each kidney was 4 mm. above the crest; and in a third 17-cm. fetus the lower pole of the *right* kidney was 8, and that of the left 3.5 mm. above the crest.) The highest and lowest points of the suprarenal glands lie at exactly the same level, but whilst the left suprarenal gland "descends" upon the anterior surface of the kidney to the highest point of the renal hilum, the right lies in contact simply with the upper pole and adjacent part of the *outer* border of the right kidney, and is not at all in front as is the case in other fetuses of this size where the kidney lay higher. Note also the differences in the relations of the ovarian arteries to the kidneys. The ilium is quite closely bound to the right ovary and Fallopian tube by a genito-mesenteric fold of peritoneum. In relation to this fold the mesentery has been slightly lowered by adhesions (indicated by the stippling). (+ indicates a small central part of the posterior parietal peritoneum.)

to the bowel, and bounded a foramen through which I could readily thrust a loop of small intestine.

Appendices epiploicæ may join together two different parts of the large intestine. This is seen in adult A (see fig. 2). In several adults I have noted the presence of foramina in large free appendices epiploicæ.

In some cases they are bounded by a thin edge, immediately around which the fold contains little or no fat, and have the appearance of having been produced by absorption. In other cases they may quite well be formed by the fusion together of two parts of the same fold (see fig. 4) or of two separate appendices epiploicæ. But it is noteworthy that in no specimen did they interrupt the line of origin of the fold, although they sometimes lie quite close to the attached border; and I have not as yet seen them in the fœtus.

Fig. 6 indicates an ordinary type of colon and its relations to parietal structures. In adult B (fig. 3) the terminal part of the ileum was fixed to the parietal peritoneum by what was probably a very small remnant of the genito-mesenteric fold; and between this fold and the ileo-cæcal junction seemed as it were to have become too long to lie in a straight line. At all events, although not actually kinked, it formed a curve convex upwards.

Fig. 3 and fig. 8 of my paper in the *Proceedings of the Royal Society of Medicine*, February 1914, indicate very clearly one of the ways in which an acute and permanent flexure of the terminal part of the ileum may be produced. The two ends of a fixed portion of this are in some cases approximated if the cæcum be able to complete its descent.

In adult A (see fig. 2) the colon had undergone considerable modifications. By the great omentum the right part of the transverse colon was closely and firmly bound to the ascending colon downwards to a point  $\frac{3}{4}$  inch from the ileo-cæcal junction. The transverse colon then passed to the left and then downwards to reach the iliac colon, to which it was firmly bound by an appendix epiploica, at a point 1 inch from the external iliac artery. It then ascended to a normally placed splenic flexure. In this part of its course it lay directly in front of the iliac and descending colons, no small intestine intervening, as of course is normally the case. The descending colon was completely hidden behind it. In the upper  $1\frac{1}{2}$  inch of its course adhesions bound it directly to the anterior surface of the descending colon.

A distinct ascending mesocolon, when it exists, is often formed very largely through stretching of the mesentery during the descent of the cæcum. For this reason flexures when found upon the ascending colon are usually of the nature shown in fig. 1, and usually temporary. On the other



hand, I have often found the sub-splenic loop (see fig. 7) upon the upper part of the descending colon, and have always seen it as a permanent loop. It occurs in the fœtus and adult, and is always antero-posterior in direction.

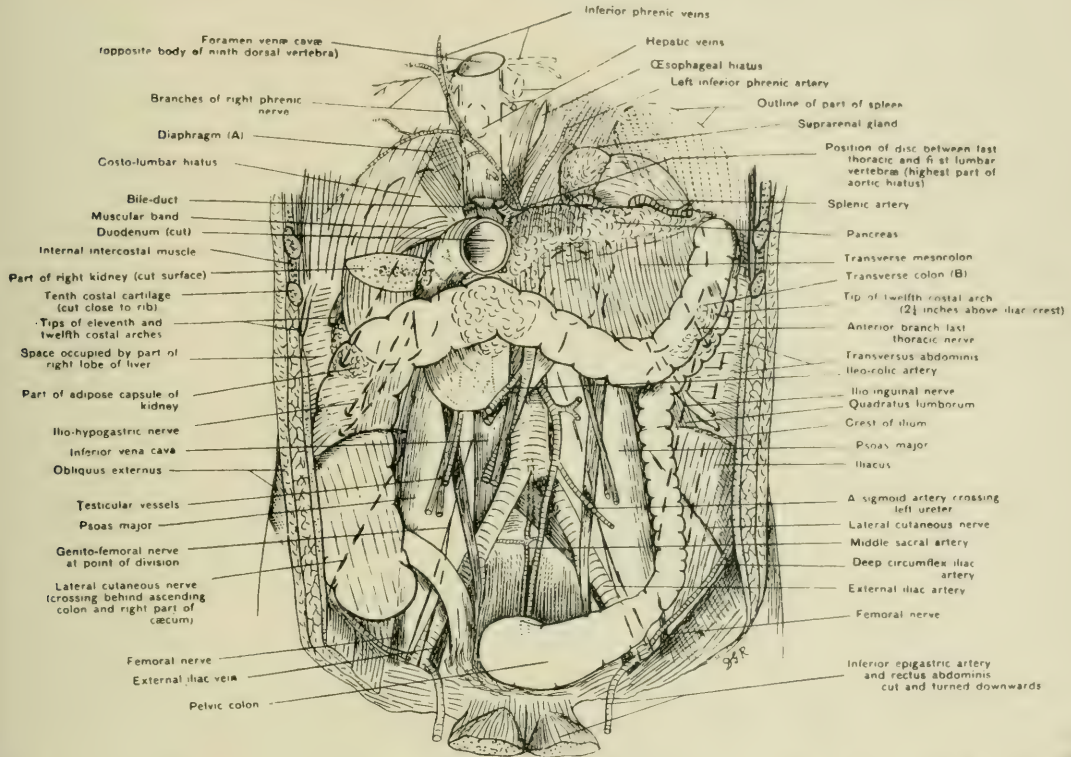


FIG. 6.—Adult. The posterior relations of an ordinary type of colon are indicated. The anterior branch of the last thoracic nerve pierces the tendon of transversus abdominis 1 to 1½ inches above the crest of the ilium and ½ to 2 cm. external to the outer border of quadratus lumborum. On the right side it is separated from the upper end of the ascending colon by the kidney and its adipose capsule. The nerve also lies behind the descending colon, but is separated from this by the part of the adipose capsule which is wedged into the dihedral angle between the lateral border of the kidney and the tendon of transversus abdominis. The transverse colon at (B) is, of course, normally separated from the descending colon by coils of small intestine (*cf.* adult B, fig. 3). The two chief variations in the course of the descending and iliac colons are indicated by continuous and interrupted lines. At (A) there is a decussation of the costal and lumbar parts of the diaphragm, the former passing in front of the latter. The “muscular band” lies parallel to the lateral lumbo-costal arch. It passes from the medial lumbo-costal arch to join the costal fasciculi of the diaphragm. It is absent on the left side where the fasciculi which usually arise from the lateral lumbo-costal arch are completely absent and there is a large costo-lumbar hiatus. The muscular fasciculi which bound the Œsophageal hiatus come entirely from the right side, the deeper (more posterior) fibres passing to the left, and the more anterior to the right of the Œsophagus. As in the fœtus the ileo-colic artery arises from the superior mesenteric vessel as this is crossing the third part of the duodenum. Primitively it always courses along the root of the mesentery. The descending and iliac colons are very narrow. The latter inclines slightly outwards. Students at the stage when they remove the large intestine are recommended to make a careful dissection to expose the parts which lie behind the ascending and descending portions of the colon. The trigonum lumbale (Petiti) should also be dissected from the front as well as from behind.



It is an acute flexure, and is permanent owing to the firm fusion together of its limbs and the loss of its mesentery. Sometimes it also adheres to the lateral parietal peritoneum, with which it lies in contact.

In foetus No. 1 (fig. 1) another antero-posterior loop is seen upon the lower part of the descending colon just above the crest of the ilium. But it had a mesentery, continuous with that of the ilio-pelvic colon, and was therefore not a permanent flexure. The sub-splenic loop is, without much doubt, also formed whilst the upper part of the descending colon is still free.



FIG. 7.—Foetus No. 3, ♂, full-time. Viewed somewhat from the left side. The sub-splenic loop lies between two strips of white paper. It is really antero-posterior in direction and lay in contact with the lateral abdominal wall (turned back) to which it did not adhere. A broad strip of white paper has been placed above the *left colic loop*, which forms a very acute flexure. Another strip of white paper indicates the fold of transverse mesocolon below the right limb of the loop.

In the foetus, as in the adult, the descending colon may curve inwards in relation to the lower extremity of the kidney and then closely skirt the outer border of the psoas (see fig. 5). In many other cases (see figs. 2, 3, and 6) it descends without so curving inwards, and along with the upper part of the iliac colon forms with the lateral border of psoas an angle of variable size. In some cases it is the pelvic colon which prevents this curve.

In other cases the pelvic colon lies to some extent in front and in other cases even partly lateral to the lower end of the descending colon. We have now indicated in the foetus most of the modifications which the pelvic colon may produce in the peritoneum and in the position, form, or direction

of viscera (including of course the genital gland, and especially the left ovary and Fallopian tube). (Other points regarding the relations of the colon, etc., are shown in fig. 6.) Fig. 7 also indicates how in the case of the transverse colon the left colic loop of Jonnesco may come to form an acute flexure. The fold (containing two arteries, one along its free border) of transverse mesocolon is seen which has resulted from the movement of the right limb upwards and to the left towards the left limb of the loop.

For other variations in the form of the intestines see my papers in the *Journal of Anatomy and Physiology*, the *Proceedings of the Royal Society of Medicine*, February 1914, and the *Transactions of the Medico-Chirurgical Society of Edinburgh*, 1913-14.

The retro-pancreatico-duodenal fossa was present, well marked, in one of the adults dissected last term (May 1914). It descended beyond the first portion of the duodenum and behind the upper part of the head of the pancreas; but the caudate lobe (process) of the liver did not descend to separate its anterior and posterior walls from contact with one another.<sup>1</sup>

An "intermediate" retro-duodenal fossa, 8 cm. long, was present in another adult. Its orifice lay immediately behind the highest part of the left border of the fourth portion of the duodenum, and was just large enough to admit the little finger. The fossa descended behind the left part of the posterior surface of the fourth portion, and then along the lower border of the third portion, of the duodenum. It terminated at the right border of the aorta, opposite the superior mesenteric vein, in the interval between the superior mesenteric artery and its ileo-colic branch (see fig. 6). I have already figured a very similar fossa in the adult.

<sup>1</sup> I must here refer to C. M. Jackson's paper "On the Topography of the Pancreas in the Human Fœtus," *Anatomischer Anzeiger*, Band xxvii., 1905. I regret that at the time I wrote on the duodenum this interesting paper had escaped my notice.

THE TOPOGRAPHICAL AND APPLIED ANATOMY OF THE GALL-BLADDER AND BILE-DUCTS. By R. J. McCONNELL, M.B.,  
*Demonstrator of Anatomy, Queen's University, Belfast.*

(Read at the Glasgow Meeting of the Anatomical Society, June 1914.)

IN most text-books of anatomy the gall-bladder and extra-hepatic bile-ducts are only very briefly described. The large and increasing number of operations now being performed on the biliary apparatus would seem to render unnecessary any excuse for the more detailed description given here.

In order to determine exactly the topographical anatomy of the gall-bladder and ducts, thirty-one subjects were carefully examined. Of these, twenty-three were ordinary dissecting-room bodies, in which special dissections were made. Five were bodies which had been frozen and sectioned, four in transverse and one in sagittal planes, by Professor Symington, the late Professor Dickey, and Mr P. T. Crymble.

Reconstructions displaying the biliary apparatus, adjacent organs, ribs, etc., from the front were made in all five; and in two, separate reconstructions were made, showing the same organs from the right side. Three fœtuses were also studied.

The examination of this material showed that the usual description of the bile-ducts is very inadequate, and emphasised the importance of studying anatomy, not only by ordinary dissection, but also by means of serial sections. Reconstructions made from such sections furnish by far the most accurate method of determining the position and relations of organs, or the course of such a structure as the common bile-duct.

I am unable to find in English text-books of anatomy any reference to the marked bend in the course of the common bile-duct, or to the fact that the middle division of the duct, which includes the bend, is firmly fixed, while the positions of the first and third divisions are easily influenced by movements of related viscera.

I think it best to describe the ordinary anatomy of the gall-bladder, cystic, common hepatic, and common bile-ducts in the above order, and then in the same order their applied anatomy.

The diagrams (figs. 1 and 2) represent the normal relations of the gall-bladder and ducts viewed from the front and right side respectively. For the sake of clearness the portal vein was omitted, and no attempt made to depict the liver.

## THE GALL-BLADDER.

The gall-bladder, pyriform in shape, lies in a fossa on the inferior surface of the right lobe of the liver. For descriptive purposes it is divided into three parts—the fundus, the body, and the neck, which is continuous with the cystic duct. It is directed obliquely from before backwards and medially, so that the fundus, which is the most anterior part, lies at a lower level and further from the middle line than the neck (fig. 1).

With the exception of the superior surface of the body, which is

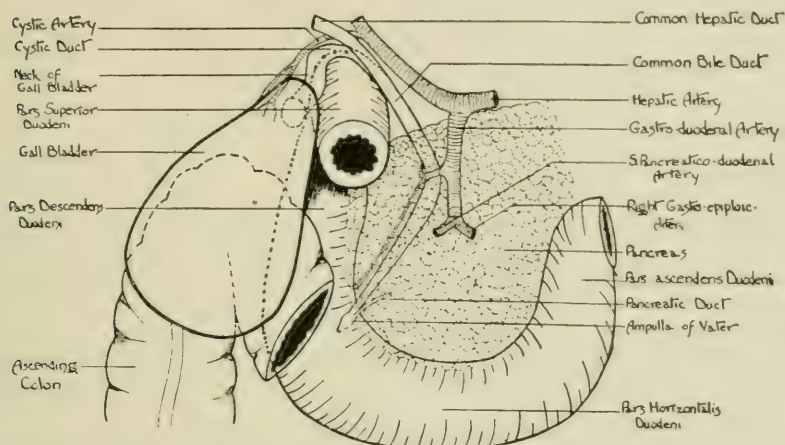


FIG. 1.—Diagram showing the relations of the gall-bladder and extra-hepatic bile-ducts viewed from the front. The artery hooking round the bend (slightly exaggerated) in the course of the common bile-duct is not labelled. The line indicating the neck of the gall-bladder also indicates the position of the cystic gland.

attached to the liver by areolar tissue, the gall-bladder is covered by peritoneum. In some cases, however, the peritoneum surrounds it completely and forms a short mesentery, attaching it to the liver.

## RELATIONS.

*The Fundus.*—Completely covered by peritoneum, the fundus usually projects beyond the sharp margin of the liver and lies in contact with the anterior abdominal wall, about the junction of the transpyloric and right lateral planes. Below, it rests on the right colic flexure and the first part of the transverse colon.

*The Body.*—The superior surface of the body is attached to the liver by areolar tissue and some small veins, the other surfaces being covered by



peritoneum. The infero-lateral surface is related to the right colic flexure, and the infero-medial to the superior and descending parts of the duodenum (figs. 1 and 2).

*The Neck.*—The neck, beginning below the highest point of the body, curves upwards and forwards, and then, bending suddenly backwards and downwards, becomes continuous with the cystic duct (fig. 2). It is covered by peritoneum, except on its anterior and superior surfaces. The anterior surface is in contact with the body of the gall-bladder, and the superior surface connected with the liver by loose areolar tissue through which passes the cystic artery and in which lies frequently a small lymphatic gland.

Inferiorly it is related to the first part of the duodenum.

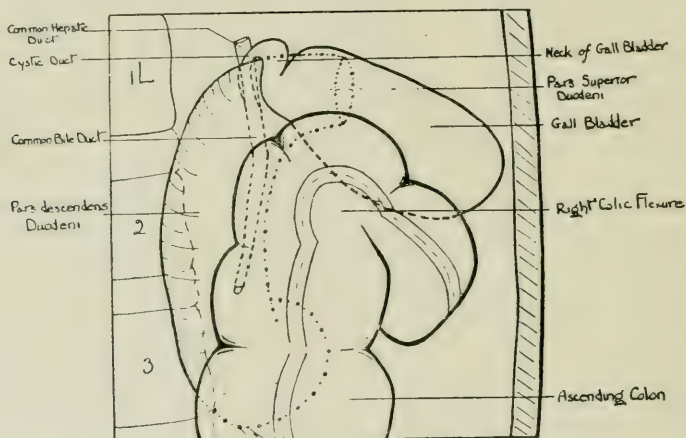


FIG. 2.—Diagram showing the relations of the gall-bladder and extra-hepatic bile-ducts viewed from the right side. Note the bend concave posteriorly of the common bile-duct. 1 L, 2, 3, bodies of first three lumbar vertebrae.

*The Cystic Duct.*—Lying in the highest part of the free margin of the gastro-hepatic omentum, the cystic duct passes downwards, backwards, and medially over the first part of the duodenum. It runs for a short distance parallel with and adherent to the postero-lateral aspect of the common hepatic duct before joining it to form the common bile-duct (figs. 1 and 2). The cystic artery courses to the gall-bladder along the antero-superior aspect of the duct; the portal vein lies behind, the hepatic artery to the left.

The external appearance of the cystic duct gives little or no indication of the size of its lumen owing to the presence of folds of mucous membrane, which, arranged in a spiral manner, project into the channel and render it

small and tortuous. These folds constitute the spiral valve of Heister, and into their structure enter, not only mucous membrane, but also non-striated muscle (continuous with the circular fibres of the duct (1)) and a framework of connective tissue.

### THE COMMON HEPATIC DUCT.

The right and left hepatic ducts unite in the transverse fissure of the liver to form the common hepatic duct. This duct, running medially downwards in the gastro-hepatic omentum lateral to the hepatic artery, and in front of the portal vein and cystic artery, joins the cystic duct to form the common bile-duct.

### THE COMMON BILE-DUCT.

The peculiar course of the common bile-duct, its varying relations at different levels, and the different routes by which the surgeon gains access to it, render its description in three stages advisable.

Charpy (2) describes three portions—a superior or duodenal, a middle or pancreatic, and an inferior or intra-parietal. This is the best method of subdividing the duct; but since the inferior part is more intimately related to the duodenum than the superior, I think it better named duodenal, while the superior may be called supra-pancreatic.

*The Superior or Supra-pancreatic Division.*—Formed at the level of the first lumbar vertebra (figs. 1 and 2) by the junction of the cystic and common hepatic ducts, the supra-pancreatic portion of the common bile-duct proceeds downwards, backwards, and medially to the upper border of the head of the pancreas. It lies in the free edge of the gastro-hepatic omentum with a few lymphatic glands around it; the portal vein lying behind, the duodenum lateral, and the hepatic artery medial.

*The Pancreatic or Middle Division.*—Continuing for a variable distance in the same direction as the superior part, the pancreatic division then bends to the right, passes downwards, backwards, and laterally, and, accompanied in its terminal few millimetres by the main pancreatic duct, reaches the postero-medial aspect of the descending part of the duodenum. It lies either in a groove on the posterior surface of the head of the pancreas, or in a canal in its substance. In the former position it is merely separated from the inferior vena cava by some connective tissue. The gastro-duodenal artery, lying on an anterior plane, gives off a large branch which passes backwards through the head of the pancreas, and, having reached the common bile-duct at the level of the bend, divides; one branch, hooking round the duct, gives twigs to it and the pancreas;

the other, coursing along the lateral aspect of the duct, reaches the duodenum.

A number of large sympathetic nerve fibres pass to the median aspect of the duct. These course either in the substance of the pancreas or along its posterior surface. They are not accompanied by blood-vessels.

*The Inferior or Duodenal Division.*—Accompanied by the pancreatic duct, the inferior division of the common bile-duct pierces very obliquely the walls of the descending part of the duodenum. Both ducts terminate by opening into a common dilatation, known as the ampulla of Vater, which communicates with the lumen of the duodenum through a minute orifice situated on the apex of a small papilla.

In short, then, the complete course of the common bile-duct is as follows:—From its origin, it first passes downwards to the left and slightly forwards as far as the hooking artery in the pancreatic substance. From this to its opening into the duodenum it passes downwards to the right and slightly backwards. Thus it displays a double curvature; the more pronounced having its convexity directed to the left, the other having its convexity forwards (figs. 1 and 2).

*Blood-supply.*—The cystic artery (fig. 1), which is a branch of either the hepatic or its right division, passes behind the common hepatic duct and, coursing along the antero-superior aspect of the cystic duct, reaches the gall-bladder. It then divides; the superior branch supplying the upper surface, the inferior the lower. The veins enter the portal system, some on the superior surface of the gall-bladder piercing the liver.

The common bile-duct is supplied by a branch of the gastro-duodenal artery, and at its terminal part by the superior pancreatico-duodenal artery.

*Lymphatics.*—Practically all the lymph from the gall-bladder drains into the cystic gland, and from it through a series of glands arranged along the course of the bile-ducts. Efferent vessels from these communicate with the pancreatic glands.

*Nerve-supply.*—The gall-bladder is supplied by branches of the vagi nerves and sympathetic fibres from the cœliac plexus. The segments from which the sympathetic fibres arise are the 7, 8, 9, 10 thoracic (3).

#### APPLIED ANATOMY.

*Gall-bladder.*—The gall-bladder is related to the sub-hepatic region (right sub-phrenic intra-peritoneal space) of the greater peritoneal sac. Gall-stones may, therefore, enter this sac, or a general peritonitis result from perforation (fig. 3).

A right, sub-phrenic, intra-peritoneal abscess not infrequently occurs



with cholecystitis; and the relations of the peritoneum show that if adhesions are present in certain localities, pus may be readily limited to this area. The abscess cavity is bounded above by the peritoneum, covering the under surface of the right lobe of the liver, and by the coronary and right lateral ligaments: in front and below by the transverse colon,

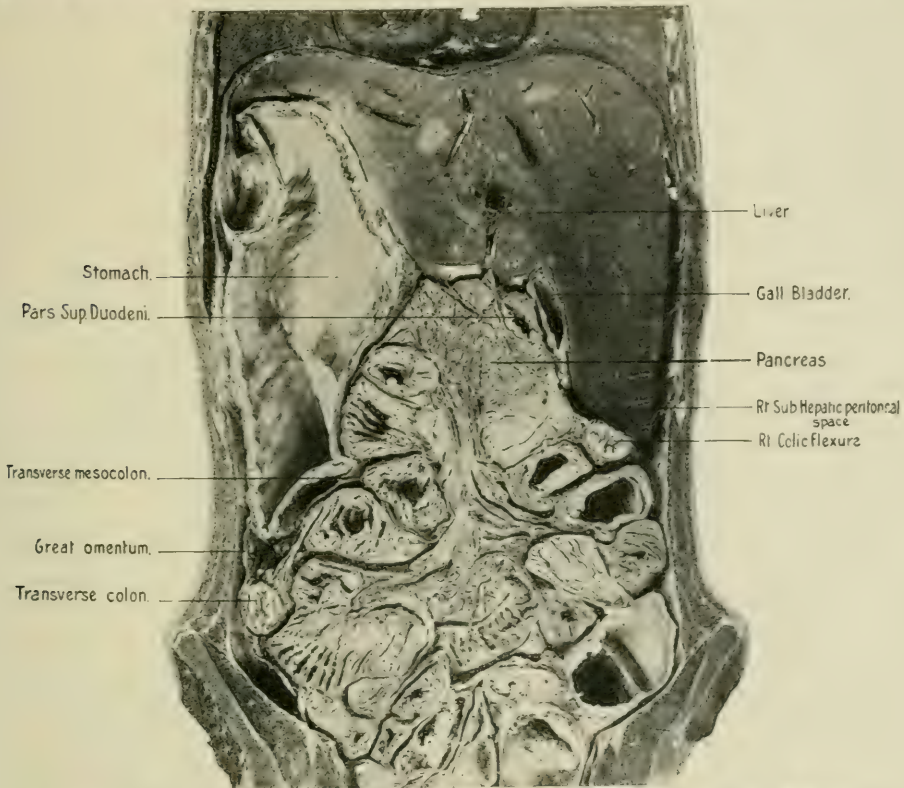


FIG. 3.—Photograph of a coronal section of a male aged 12, viewed from behind. Note the relation of gall-bladder to the pancreas, duodenum, and the sub-hepatic peritoneal space.

adherent to the liver and anterior abdominal wall, or by a fold of great omentum (fig. 12) adherent to the liver and colon: laterally by the peritoneum on the lateral abdominal wall: and medially by duodenum and by adhesions closing the foramen of Winslow.

With the liver in normal position, the neck of a distended gall-bladder projects upwards and medially between the layers of the gastro-hepatic omentum (fig. 4), thus admitting the possibility of gall-stones entering the lesser sac, or of suppuration involving either the portal vein or hepatic



artery. The superior surface of the gall-bladder being devoid of peritoneum (fig. 3), a suppurative cholecystitis may directly infect the liver, and give rise to a localised abscess continuous with the cavity of the gall-bladder (4), or multiple abscesses be caused by infection spreading along the small veins which pass from the gall-bladder through the liver and communicate with the portal system.

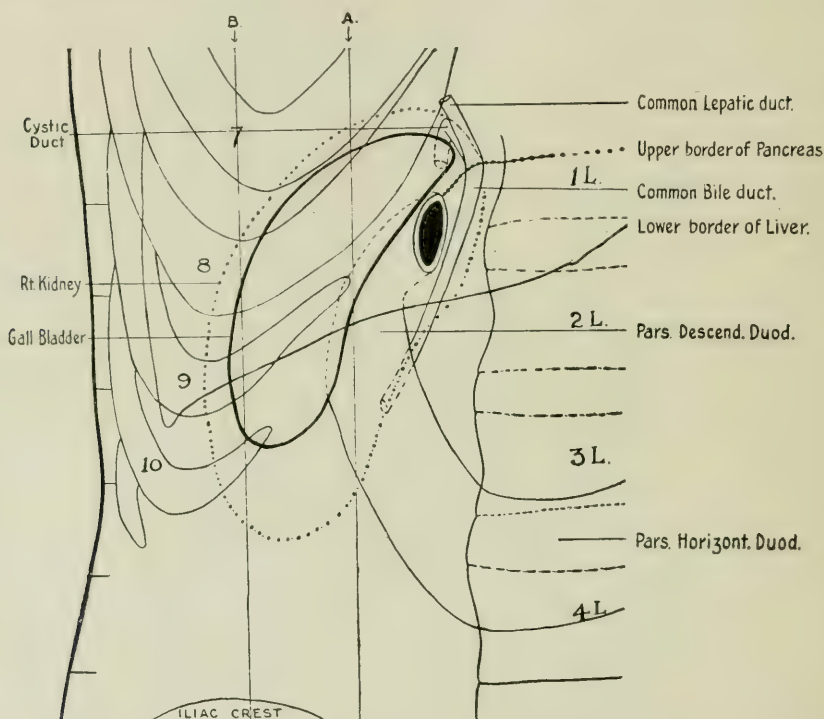
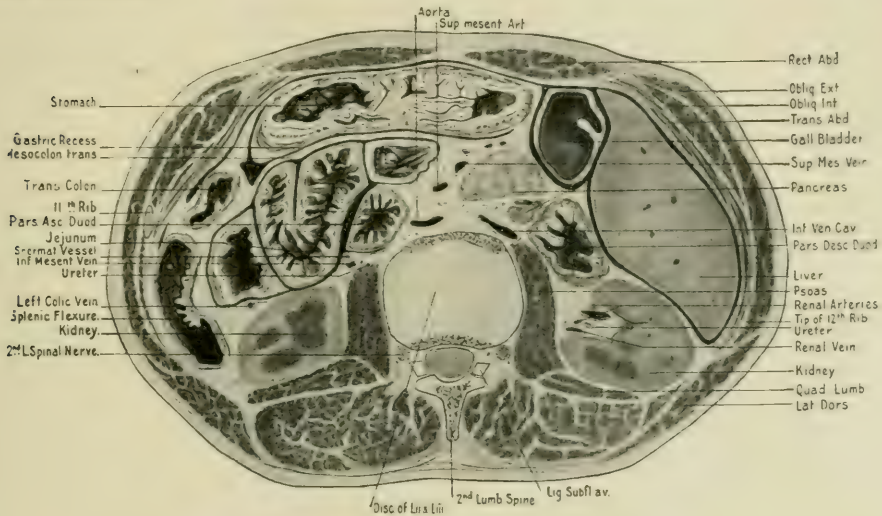


FIG. 4.—Reconstruction from a series of sagittal sections of a man aged 40, viewed from the front. Figs. 6 and 7 are drawings of two of these sections, indicated on this figure by the lines B and A respectively. Note the distended gall-bladder and the adherence of the entire cystic duct to the common hepatic duct. It will be seen that there is no supra-pancreatic division of the common bile-duct.  $\frac{1}{2}$  natural size.

In those subjects in whom the gall-bladder is suspended from the liver by a mesentery, a distended gall-bladder forms an abdominal tumour freely movable from side to side; and cases have been reported in which a localised abscess was present between the layers of this mesentery.

Enlargement of the cystic gland may cause obstruction, or the diseased gland may become adherent to the neck of the gall-bladder, and be mistaken for a gall-stone (fig. 1).

In every subject examined the gall-bladder was related to the duodenum and colon: the duodenum being related to the neck and part of the body; the colon to the body, the fundus, and occasionally to the neck (fig. 14). These relations account for the fact that gall-stones, ulcerating into the alimentary canal, usually enter either by the duodenum or the colon, but more frequently by the former. The constant relation of the duodenum to the neck of the gall-bladder, in which stones are often impacted, and its relatively fixed position, account for the more frequent involvement of the duodenum.



SECTION 13.

FIG. 5.—Transverse section at the level of the disc between the 2nd and 3rd lumbar vertebrae; man aged 50. Note relation of the gall-bladder to the anterior abdominal wall, stomach, pancreas, and the duodenum. The level of this section is indicated by the number 13 on the left side of fig. 8.  $\frac{1}{2}$  natural size.

The gall-bladder is often related to the pylorus, and in three cases was in contact not only with the pylorus, but also with the body of the stomach (fig. 5). Naunyn (5) quotes eight cases of fistula between stomach and gall-bladder.

In two cases a portion of the ileum was only separated from the fundus of the gall-bladder by the transverse mesocolon: in a third, two loops lay in contact with it (fig. 6). This relationship is unusual, but may occur if the large intestine is fixed in an abnormal position, or in cases of great distension of organs, such as the stomach, the descending colon, the bladder, or the rectum (6). Naunyn reports two cases of fistulae—one between the gall-bladder and ileum, the other between the gall-bladder and the jejunum.

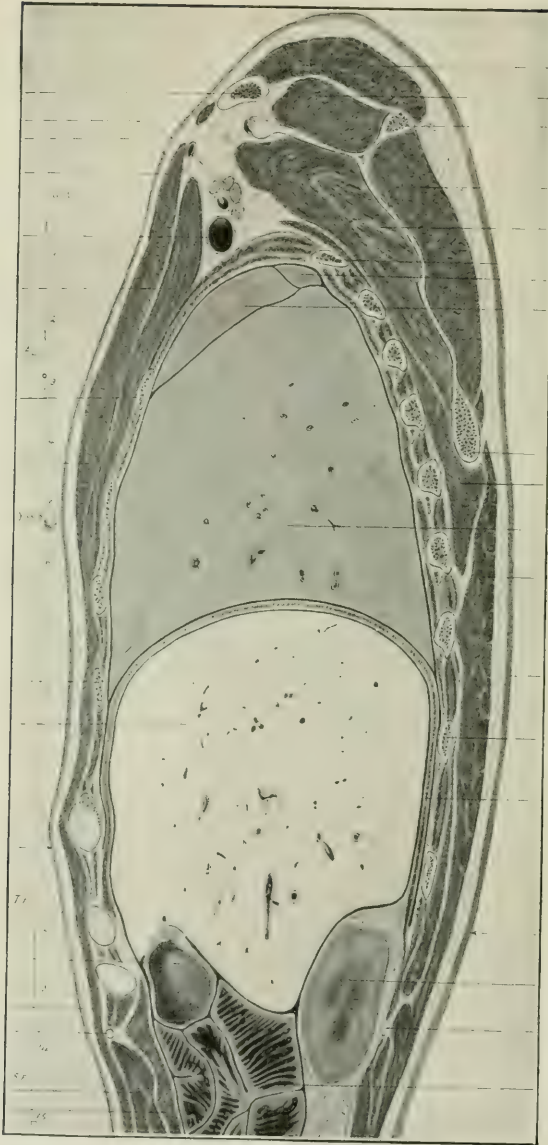


FIG. 6.—Sagittal section, line B, fig. 4, viewed from medial side. Note relation of gall-bladder to anterior abdominal wall and small intestine.

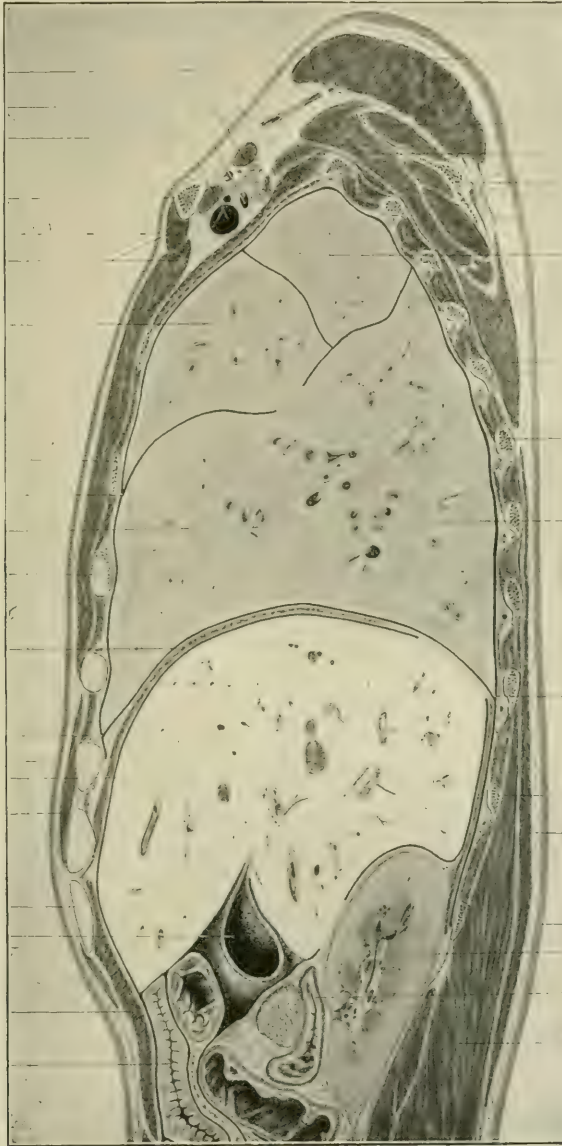


FIG. 7.—Sagittal section, line A, fig. 4, viewed from medial side. Note the proximity of gall-bladder to kidney, and that small intestine lies above and in front of the colon.





The gall-bladder fixed to the liver necessarily follows its movements, normal and abnormal. Downward displacement with anteversion rotates the fundus of the gall-bladder downwards and medially, so that it lies as near the middle line as the neck, or even nearer (fig. 8), and comes into contact with the pancreas, the pylorus, and sometimes with the body of the stomach (figs. 3, 5, 13).

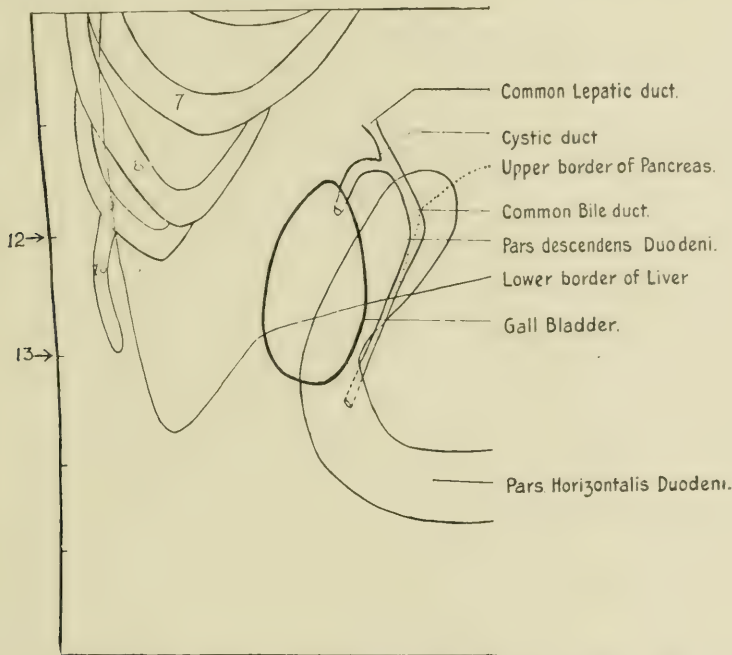


FIG. 9.—Reconstruction from a series of transverse sections of a girl aged 14. Fig. 11 is a drawing of the upper surface of the section labelled 13 on the reconstruction. Liver enlarged but not displaced; its upper-surface reached the normal level.  $\frac{1}{2}$  natural size.

The same condition may also result from simple enlargement of the liver (fig. 9).

Upward displacement with retroversion produces an outward and upward rotation of the fundus, so that it may lie in the mid-axillary line (fig. 10).

In three of the cases examined the fundus lay under the ninth rib in this line. Of these all had small livers, two had greatly distended stomachs, and in one there was a very large left pleural effusion.

The important bearing which these movements have on the course and relations of the bile-ducts will be described later.

The gall-bladder may not be in contact with the abdominal wall (fig. 11); thus, in some of the cases examined the anterior margin of the liver intervened, in one the transverse colon, in one the cæcum, and in several a fold of great omentum.

*Cystic Duct.*—In many cases it is extremely difficult to determine the junction of the neck of the gall-bladder with the cystic duct, especially when displacement of the liver exists (figs. 10 and 12). If a surgeon

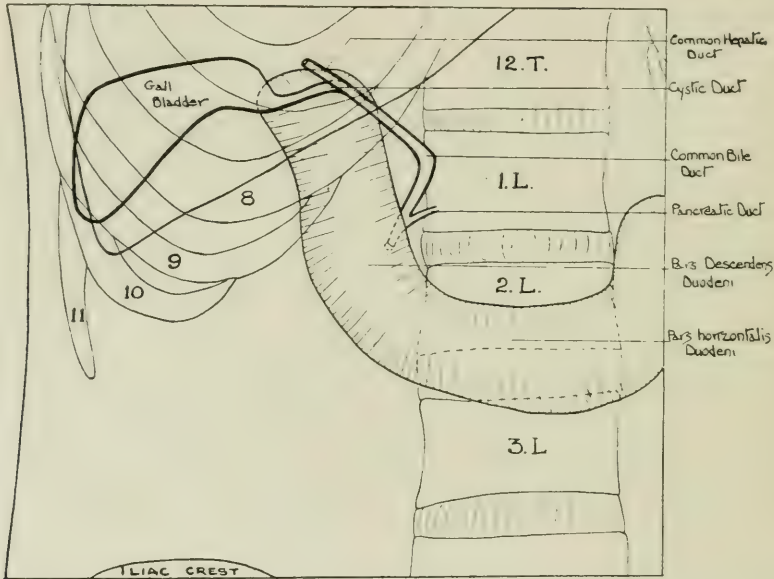


FIG. 10.—Reconstruction from a series of transverse sections of a man aged 68. The fundus of the gall-bladder is related to abdominal wall in the mid-axillary line. Neck of the gall-bladder and cystic duct pass transversely inwards. The pars superior and pars descendens duodeni are displaced laterally. Marked bending of the common bile-duct. This reconstruction demonstrates the fixation of the pancreatic division of the common bile-duct, for notwithstanding the outward displacement of the gall-bladder and duodenum it has retained its normal position.  $\frac{1}{2}$  natural size.

performing a cholecystectomy fails to recognise the junction and does not completely remove the neck, then a miniature gall-bladder remains in which stones may form (8). In these cases, however, the cystic duct is not adherent to the common hepatic duct, or only for a very short distance; hence its terminal portion is easily recognised.

Outward and upward displacement of the gall-bladder straightens out the neck and cystic duct, so that they run transversely towards the middle line (fig. 10), a condition which favours the passage of fluids from the gall-bladder into the common bile-duct. Traction of the liver in an upward

and outward direction may therefore facilitate the passage of a probe through the cystic duct, an operation which, judging from the structure of the duct, one would not think likely to succeed without serious injury to the spiral valve.

The adherence of the terminal part of the cystic duct to the common hepatic duct is of supreme surgical importance. Numerous cases have been reported in which the latter was injured during operation (9), or mistaken for the cystic duct and ligatured. These accidents are most likely to occur when the gall-bladder is distended and the liver in normal



FIG. 11.—Transverse section of a girl aged 14 at the level of the disc between the 1st and 2nd lumbar vertebrae. Note the relation of the fundus of the gall-bladder to the sub-hepatic peritoneal space, to the pancreas, and to the duodenum, and that it is separated from the abdominal wall by a fold of great omentum. The common bile-duct lies in a groove on the post-surface of the head of the pancreas and could easily be reached by turning forwards the duodenum. The level of this section is indicated on fig. 9 by the number 13.  $\frac{1}{3}$  natural size.

position, because the neck projects medially upwards between the layers of the gastro-hepatic omentum and lies in contact with the common hepatic duct, the entire cystic duct being adherent to the latter (fig. 4).

Practically all forms of liver displacement tend to straighten out the cystic duct, but, as will be shown later, marked ptosis may produce a very acute bend in the cystic duct near its junction with the common hepatic duct, thus favouring obstruction at this point.

According to Professor Keith (10), the function of the spiral valve is to maintain the patency of the cystic duct; but since the folds forming this valve contain muscular fibres, continuous not only with those of the circular coat of the duct (11), but also, to a lesser extent, with those of



the longitudinal coat, one must assume that it has the power either to diminish or increase the size of the lumen. The position of the cystic artery is very constant. It may, however, pass in front of instead of behind the common hepatic duct.

*The Supra-pancreatic Division.*—This division of the duct, deeply situated above and behind the sharp margin of the liver and ribs, is difficult to reach for surgical purposes. Upward displacement of the liver, with retroversion, renders it more accessible (fig. 14).

The lower part of its posterior surface is often devoid of peritoneum, and is separated from the inferior vena cava by some lymphatic glands. These glands may be diseased and closely simulate gall-stones.

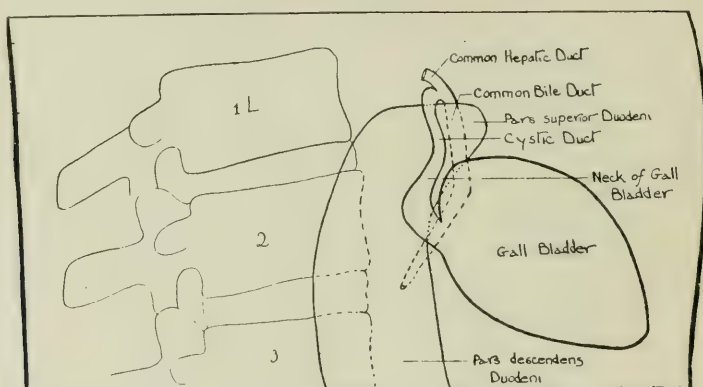


FIG. 12.—Reconstruction from a series of transverse sections of a man aged 50, viewed from the right side. Note that the cystic duct passes upwards and joins the common hepatic duct at an acute angle 1 L, 2, 3, bodies of first three lumbar vertebrae.  $\frac{1}{2}$  natural size.

In a small percentage of subjects the right hepatic artery is a branch of the superior mesenteric and courses upwards in close relation to the duct, sometimes lying in front of it, or even lateral to it. In the latter position it may readily be injured during operation.

Fistulae between the duct and the duodenum, or even the stomach, may occur. Naunyn (5) collected fifteen cases of the former condition, and cases of the latter have also been recorded (4).

The majority of the nerve fibres passing to the liver lie median to the duct. Many, however, pass up in close relation to it. Crile (8) thinks that the high mortality rate in common-duct operations is due to injury of these nerves, and lays great stress on gentle manipulation, infiltration of the tissues with novocaine, and sharp dissection as a means of reducing the mortality.

*Pancreatic Division.*—The varying relations of the pancreatic division

of the duct to the head of the pancreas are of surgical importance (figs. 11 and 13).

It is usually located by cutting the peritoneum binding the pars descendens duodeni to the posterior abdominal wall and pulling this viscus forwards and to the left.

In all cases it is best to begin at the lower part of the duodenum and work upwards, because the terminal few centimetres of the duct are easily

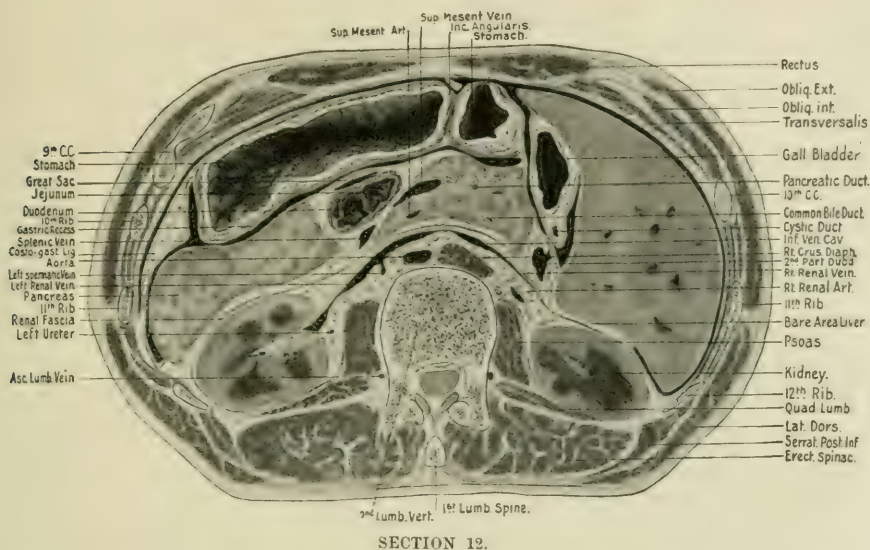


FIG. 13.—Transverse section at the level of the 2nd lumbar vertebra. Man aged 50. Note the position of the common bile-duct; it lies in a canal in the substance of the pancreas, at a considerable distance from the duodenum, and would be difficult to reach for surgical purposes (compare with fig. 11). The level of this section is indicated on fig. 8 by the number 12.  $\frac{1}{3}$  natural size.

located, whereas the remainder may be embedded in the head of the pancreas (compare figs. 11 and 13). In performing the operation care must be taken of the artery (often large) which courses along the lateral aspect of the duct. Haemorrhage, serious and difficult to control, may result from injury to this vessel.

*The Duodenal Division.*—Gall-stones frequently become impacted in the ampulla of Vater, and obstruct not only the flow of bile but also the pancreatic secretion. They are removed by transduodenal choledochotomy.

*Effects of Liver Displacements on the Extra-hepatic Bile-ducts.*—The displacements of the liver that I would specially draw attention to are the

upward displacement with retroversion, and the downward displacement with anteversion.

In the former condition, the axis of rotation having a direction downwards, forwards, and to the right, the fundus of the gall-bladder is carried outwards and upwards, and the cystic duct—the termination of which lies nearer the centre of rotation and is more or less fixed by the gastro-hepatic omentum and by sympathetic and vagal nerve fibres—necessarily straightens out, without much tendency towards kinking. The common bile-duct, however, as a result of this rotation, has a decided tendency to kink. The supra-pancreatic division, and that portion of the pancreatic division which lies above the hooking artery, straighten out, assume a more horizontal position, and are under a certain degree of tension, thus rendering more acute the bend in the pancreatic division. In cases such as fig. 10, where the duodenum is also involved in the displacement, this bend becomes still more acute as the duodenal division of the common bile-duct and that portion of the pancreatic division which lie distal to the hooking artery rotate upwards and laterally, with the hooking artery as the centre of rotation.

In downwards displacement, with anteversion, the fundus of the gall-bladder moves through a large arc downwards and medially. The cystic duct again, lying nearer the centre of rotation, moves in the same direction, but in a smaller arc, and having its termination somewhat fixed, tends, as before, to straighten out, coursing, however, not in a horizontal but in an upward and medial direction.

A further effect of this traction is that the areolar tissue binding the cystic duct to the common hepatic duct is gradually stretched and the cystic duct drawn away, leaving in some cases merely a small portion at the very termination still adherent to the common hepatic duct. It is at this point that a kink may result, causing obstruction. The cystic duct having been straightened out, traction produced by any further displacement of the liver then acts on that portion of the common bile-duct proximal to the bend, rendering it more acute, and thus producing a condition likely to cause obstruction.

Fig. 14 is a photograph of a male subject, aged 62, whose gall-bladder was injected with hot gelatin. On exposing the gall-bladder and ducts, I found the injection had distended the gall-bladder, the cystic and hepatic ducts, but had only filled that portion of the common duct which lies proximal to the bend. In this subject the liver was displaced upwards and outwards so that the fundus of the gall-bladder almost reached the mid-axillary line. This displacement, by pulling on the supra-pancreatic part of the duct, caused kinking and obstruction at the level of the bend,



where a large artery is seen hooking round the duct. The majority of nerve fibres pass to the medial aspect of the duct, and are best avoided by working along its lateral aspect.

Although the mere retention of bile in the gall-bladder is not sufficient to produce gall-stones, still it is one of the most important predisposing factors to their formation.

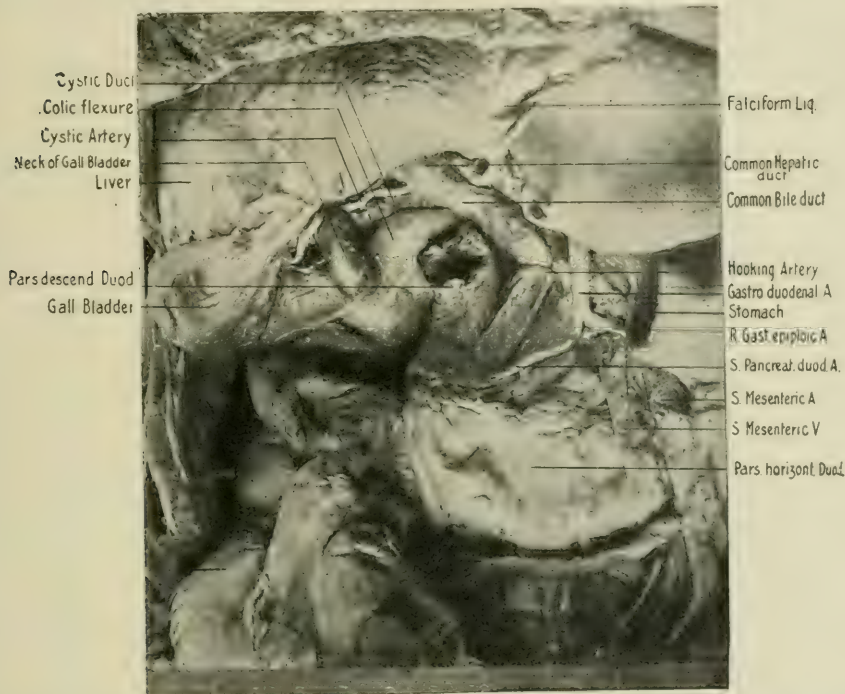


FIG. 14.—Photograph of the gall-bladder, bile-ducts, etc., of a male aged 62. In this subject the following dissection was made:—The anterior abdominal wall was removed and the gall-bladder injected with gelatin, the structures in the gastro-hepatic omentum were then cleaned and the pylorus and pars superior duodeni excised. The common bile-duct, the gastro-duodenal artery and its branches were dissected out, and the head of the pancreas removed. The subject was then placed in the supine position and photographed with a vertical camera

Gall-stones are rare in subjects under thirty, and common in those over fifty. They occur more frequently in women than in men, and of the former they are more frequent in those who have borne children. The common feature in these cases is an increasing tendency to lax abdominal walls, and consequently to enteroptosis. According to Professor Keith (10), gall-stones and enteroptosis are almost invariably concomitant. As has already been explained, the pancreatic division of the common duct is



firmly fixed, while the first and third divisions are readily affected by displacement of the liver and duodenum respectively. These displacements tend to produce kinking of the duct at the level of the bend, thus causing stasis, and creating a condition favourable to microbial activity.

A consideration of the anatomy of the common bile-duct possibly explains the frequent and rapid return of the symptoms of cholelithiasis after cholecystotomy has been performed. As long as the patient remains in bed there is little or no traction of the liver on the common duct, but with the assumption of the upright position displacement and traction may again occur.

It would seem, therefore, that in patients who have had biliary colic, or who have had operations on the gall-bladder, every measure should be taken to improve the tone and power of the abdominal muscles.

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OBSERVATIONS ON CERTAIN STRUCTURAL DETAILS OF THE  
NECK OF THE FEMUR. By THOMAS WALMSLEY, M.B., *Demon-  
strator of Anatomy, Glasgow University.*

THE neck of the femur is a flattened arc of bone connecting the head with the upper extremity of the shaft, passing inwards, upwards, and forwards from the shaft at an angle of individually varying magnitude. The flattening of the neck is from before backwards, and it is narrowest at its middle part, expanding at both extremities, but more so at its outer end where it becomes continuous with the shaft. The vertical diameter of the outer end derives its increase, partly from the manner in which the lower border of the neck passes downwards into the inner border of the shaft (Adams' arch),

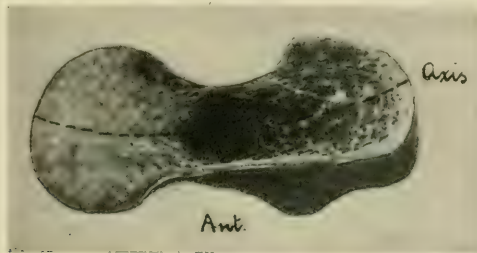


FIG. 1.—Horizontal section of neck and head of femur, showing convexity forwards.

though in addition the whole neck here undergoes an enlargement in all its dimensions. The inner extremity of the neck is more circular in conformity with its attachment to the base of the head, the demarcation being best defined by what is hereinafter termed "the base-line of the head" (*vide post*). Taken as a whole, and as seen on horizontal section (fig. 1), the neck has a slight curvature with the convexity forwards—that is, opposite in direction to the curve which is found at the junction of the base of the neck with the upper end of the shaft.

The anterior surface of the neck extends from the base-line of the head anteriorly to the external limit of the anterior intertrochanteric roughness. For descriptive purposes this surface is here divided into two parts, an outer smooth area, and an inner usually rough area, separated from one another by a hitherto undescribed ridge (figs. 2, 3, and 4). This ridge is

absolutely constant in position in all adult bones, though it varies within wide limits as regards its degree of evidence. In direction it is transverse to the long axis of the neck, parallel to the anterior intertrochanteric line, and distant from that line about 1 to 1.5 cms. It is best marked towards the upper extremity of the neck, beginning, as a rule, abruptly just below the superior border, passes downwards and inwards, with a concavity directed upwards and inwards, and terminates below by gradually fading away into the general contour of the bone about half way down the neck.



FIG. 2.—Proximal extremity of femur, anterior aspect, showing "capsular ridge" in a slight degree of development.

It is thus early to be insisted on that this ridge is not merely the external limit of the medial rough area, but represents the internal boundary of and belongs to the lateral smooth area. The whole evidence of its causation demonstrates this fact. This lateral smooth area is almost comparable to the pulley on the lesser sacro-sciatic notch over which the tendon of the *m. obtur. inter.* plays at its exit from the pelvis; indeed, in many specimens examined in the recent condition, the whole formation of the superficial structures presents an almost identical appearance. On this smooth area there plays the supero-lateral part of the anterior capsule. In full extension of the limb—the position of greatest tension of its fibres—this part of the



FIG. 3.—More advanced development of "capsular ridge."



FIG. 4.—Well-marked "capsular ridge."



capsule acts in such a spiral manner as to produce this "capsular groove," concave inwards. A cartilage covering was never noted in this position. An examination of a series of fresh specimens shows how close is the relation between the capsular development and the degree of evidence of the "capsular ridge," and the marking off of the capsular groove. In young bones no such ridge is to be found, nor for that matter is there any indication of an anterior intertrochanteric line. It is about the age of eighteen years that the roughness at the anterior capsular attachment begins to appear; it is progressive in development, yet varies with the amount and strength of the capsular fibres; only subsequent to that period can evidence of the capsular ridge be found, and it is always best marked when the capsule and its attachment are well developed. Bertaux (*L'humérus et le fémur*, Lille, 1891) held that the roughness on the anterior face of the femoral neck was due to partial attachment of the fibrous capsule, a view somewhat similar to that more recently advanced by Frazer ("Some Minor Markings on Bones," *Jour. Anat. and Phys.*, vol. xl. p. 270), who holds that the roughness is due to recurrent fibres from the anterior circular set of capsular fibres. Now, it may be dogmatically insisted on that in the position of this groove there is no recurrence of capsular fibres back on the neck, neither in the fetus nor at any subsequent period. No matter into how many layers the capsule be split, each layer which has a femoral attachment at all is fixed in the region of the anterior intertrochanteric line, the retinacula being placed in their entirety either proximally or distally to this area. This lateral area, then, devoid of vascular foramina, is a pulley on which there plays the upper and outer part of the anterior capsule, and contact is closest when the limb is in full extension. These facts are made clearly evident if the finger be placed on the groove through a slit in the complete capsule, and the limb slowly extended from the position of flexion.

For the consideration of the significance of the medial area, reference must be made to the articular margin of the head of the femur. This margin is undulating, but in a regular and constant manner as regards the incidence of the causes of the unevenness, though in degree variation does occur to a considerable extent. The undulations are excursions outwards of the articular cartilage, and between these are recessions inwards, or, more correctly, recessions where the excursion of the cartilage over the neck is more limited in extent. The most marked inward concavity is placed opposite the great trochanter towards its posterior part, and bounding this concavity are two outward eminences, one towards the back and one towards the front of the neck of the femur. Of these the posterior is more localised and angular than the anterior, which is more diffuse and rounded, while in size the posterior is much the more constant. This is

proved by the fact that a series of femora may be found, even among European races, in which the anterior of these excursions is continued for some considerable distance over the neck of the femur. This variation was described by Henke (*Handb. d. Anat.*, p. 176), but no special significance was attached to it. Fick (*Handb. d. Anat. u. Mech. d. Gelenke*, Bd. i. S. 318) describes it as the "eminentia articularis colli femoris." Charles ("The Head of the Femur," *Jour. Anat. and Phys.*, vol. xx. p. 1), writing on this same structure from a study of Hindu bones, attributed the condition to an adaptive variation dependent on continuous over-flexion of the joint such as occurs in the "squatting" position. He claimed the condition as essentially Asiatic, and described the European femur as having an even articular margin when looked at from above. Neither of these conclusions can be held as correct; indeed, Parsons ("The English Thigh-Bone," *Jour. Anat. and Phys.*, vol. xlviii. p. 238) has been able to find evidences of marked unevenness in over 60 per cent. of English femora. Poirier and Charpy (*Anat. humaine*, vol. i. p. 220), in discussing this structure, point out that the head is continued down on to the neck anteriorly and posteriorly, while on the anterior face of the neck there is a rough impression, "d'empreinte iliaque," which is occasionally present as a continuation of the articular cartilage of the head. These authors explain the condition as being due to the contact of the neck of the femur with the superior part of the acetabular margin in the position of extreme flexion; but, as Fick has pointed out, considerable abduction combined with internal rotation would also be necessary before this contact could take place, and Parsons' figures emphasise the incongruity of the correlation, when heed is taken of the unnaturalness of the required position.

The medial area of the femoral neck may be found to exist in three different structural conditions, rough in about 70 per cent., almost smooth in about 20 per cent., and in the remaining 10 per cent. more or less cartilage-covered. While the anterior cartilage excursion thus varies to a considerable degree, yet its lateral margin will never be found beyond that definitely marked ridge on the neck of the femur, previously termed the capsular ridge. Now, on closer examination of this excursion in its extreme degree, it is clear that it is not in physiological continuity with the articular surface from which it springs, being curved in one direction only, antero-posteriorly, but perfectly flat in the latero-medial plane. In addition to this fact, I have never been able to find an absolutely smooth surface on one of these extreme excursions. They have never presented themselves in the young subject, and always, in my series, they have been associated with strong bony ligamentous markings, and with powerful capsular bands. Further, in no possible natural position of any of the joints could

this excursion, in any of the specimens in which it was present, be made to enter the acetabular cavity : in other words, when the anterior excursion of the cartilage from the head over the neck is present to an extreme degree, the lateral part of that excursion is never intra-articular in the sense of lying within the acetabulum. It must therefore be concluded that this condition is simply a variation of the more commonly found roughness, which, as already indicated, is placed medial to the capsular ridge. In considering what the cause of this roughness may be, it is

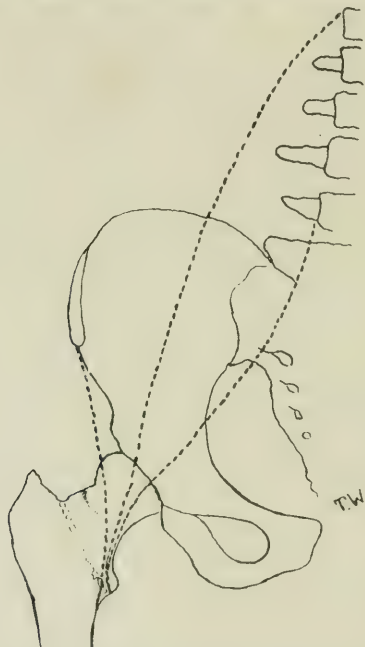


FIG. 5.—To show the usual relationship of the ilio-psoas mass to the proximal extremity of the femur.

necessary first to define the usual relationship of the tendon of the m. ilio-psoas to the proximal extremity of the femur, and especially in the position of full extension (fig. 5). The tendon of the m. psoas is certainly medial to the vertical limb of the ilio-femoral band above, so that when the bursa under that tendon communicates with the cavity of the hip-joint it does so medial to that ligament, and exposes the lateral part of the anterior cartilage of the head of the femur. The iliacus muscle, laterally placed, lies much more on the femoral neck over the vertical limb of the ilio-femoral ligament, and it will be noted that the direction of the concavity of the combined mass is upwards and outwards. Thus



any action which the ilio-psoas may have on the production of markings on the neck of the femur would not only be confined to the lower part of the femoral neck, but there only after acting through a structure more powerful and of greater extent than itself, the medial part of the ilio-femoral ligament. The ilio-psoas, therefore, cannot be made responsible for the marking in question. It is also clear from its extent that this medial rough area, or its variations, does not result from bony contact with the margin of the acetabulum, and the conclusion seems justifiable that the structural condition of this whole area rather represents the amount of contact of this portion of the neck of the femur with the vertical limb of the ilio-femoral ligament in the position of complete extension.

In addition to the two outward eminences already indicated, there was described by Goodsir (*Anat. Memoirs*, vol. ii. p. 508) a third, situated in the inferior shallower concavity at the intersection of the ridge prolonged from the lesser trochanter with the articular margin of the head. In my series, a little anterior to the above-defined position, a very slight outward projection was found in less than 10 per cent. of 200 bones examined on this particular point—a frequency not greater than that of a small outward eminence in the middle of the superior concavity.

Two other markings at the margin of the head of the bone are constant in the series of femora I have examined. First, on the inferior wall of the anterior cartilaginous excursion there is an oval area of fairly smooth, roughly polished bone, abutting against the margin of the head, but belonging to the neck, never cartilage-covered, yet sharply demarcated from the surrounding bone, and differentiated by the absence of vascular foramina. This imprint is undoubtedly produced by bony contact with the margin of the acetabulum. It is intra-synovial in position—that is, the synovial membrane ceases at its lateral border. Contact takes place between this portion of the neck and the articular margin at the anterior part of “the pubic protuberance of the acetabular rim,” in the position of complete extension. In this position, extension is combined with a certain degree of internal rotation which takes place primarily to allow the most complete reception of the head of the femur within the acetabulum, and to produce secondarily the locking of the knee-joint. When the femur is thus extended and rotated the anterior excursion of the articular cartilage of the head is in firm contact with the lower part of the iliac area and with the pubic area of the acetabulum, while the imprint described is forced to rest on the latter area at its marginal part. It is therefore proposed that this “facet of rest,” or “pressure facet,” should be termed the “pubic imprint.” In extent the pubic imprint varies a good deal, but



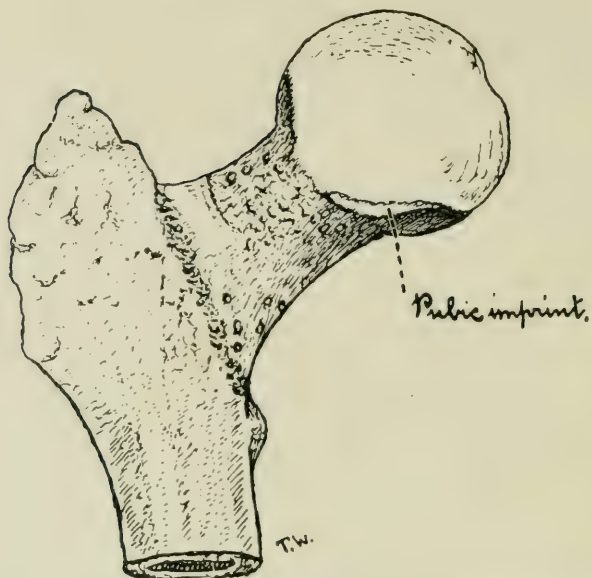


FIG. 6.—The incidence and shape of the "pubic imprint" is diagrammatically shown.

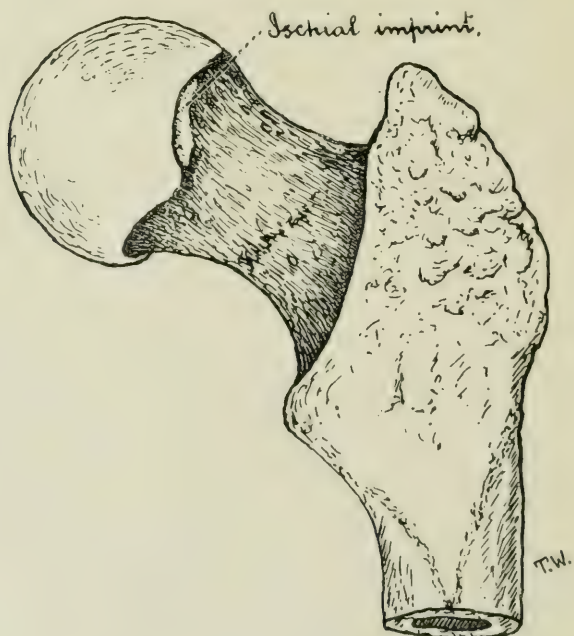


FIG. 7.—To show "ischial imprint"—diagrammatic.

a well-marked bone would show it as about 1.5 cms. long, about .8 cm. at its broadest part, of oval form but tapering away inferiorly, an incidence in conformity with its incidence of action. At twelve years of age this marking is perfectly distinct, though it is relatively smaller in size than in the adult; but previously to this period it cannot be determined with any degree of accuracy, and is certainly absent up till the sixth year.

Second, the excursion over the posterior part of the neck is, as previously stated, more constant in size than the anterior excursion. It is wholly acetabular in position when the limb is completely extended, occupying in that position the "ischial projection" of the acetabulum. By its upper border it bounds the superior concavity posteriorly, and the bone lying lateral to this boundary corresponds in structure to the pubic imprint. Thus it is proposed to describe another pressure facet on the femoral neck, also constant in position, and, though varying a little in size, of dimensions on the average very comparable to those of the pubic imprint. This facet, differentiated by similar structural characteristics, is produced in like manner to the pubic facet—that is, by contact with the acetabular margin. It is probably differentiated at a later period of life. In respect that the contact takes place with the ischial part of the acetabular rim, the facet may be termed the "ischial imprint."

These two imprints, pubic and ischial, represented in figs. 6 and 7, are most evident in the recent specimen.

THE NECK OF THE FEMUR AS A STATIC PROBLEM. By  
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University.*

THE angulation of the limbs is a beneficial structural adaptation to the mechanical requirements, and, in connexion with the proximal component of the weight-transmitting couple of which each limb consists, the two points of paramount importance, so far as the preservation of stability is concerned, are the length of the component and its degree of angulation to the distal element.

1. *The Length of the Neck.*—The purposive necessity of the essentially human characteristic of the comparatively great length of the neck of the femur has been assigned to various functional causes, most of which are open to the objection of being simply statements of fact of the existing conditions, and not explanations of those really associated circumstances. For example, it is not necessary to lengthen the femoral neck in order to obtain a greater amount of adductor muscle; rather it should be said that, the neck of the femur being lengthened, a greater amount of adductor muscle will become an absolute necessity. The length of the neck of the femur is really proportional to the breadth of the pelvis.

With the increase of the pelvic transverse diameter in relation to the pelvic antero-posterior diameter,<sup>1</sup> there has been a concomitant increase in the divergence of the lines of weight-propagation from the vertebral column to the lower limbs. For, when the antero-posterior measurements are more carefully analysed, it will be found that the reduction is purely of the post-acetabular part of those measurements; the pre-acetabular, on the other hand, undergoing a relative increase concomitant with the increase of the transverse diameter (figs. 1 and 2). While not seeking to dissociate the final correlation of the causative factor in man from the assumption of the erect position, yet it may be stated that with the increase

<sup>1</sup> Topinard, *Anthropology*, p. 305.

Duckworth, *Anthropology*, p. 295, shows this by means of an index (modified from Topinard), where, when the transverse diameter is 100, the antero-posterior is as follows:—

Edentata . . .	- 138	Lemuroidea . . .	- 144
Rodentia . . .	- 133	Cebidæ . . .	- 135
Carnivora . . .	- 132	Cercopithecidæ . . .	- 134
Ungulata . . .	- 123	Chimpanzee . . .	- 97
		Gorilla . . .	- 79
		Homidæ . . .	- 73

(Turner, *Chall. Rept.*, xlvii., average of white races):

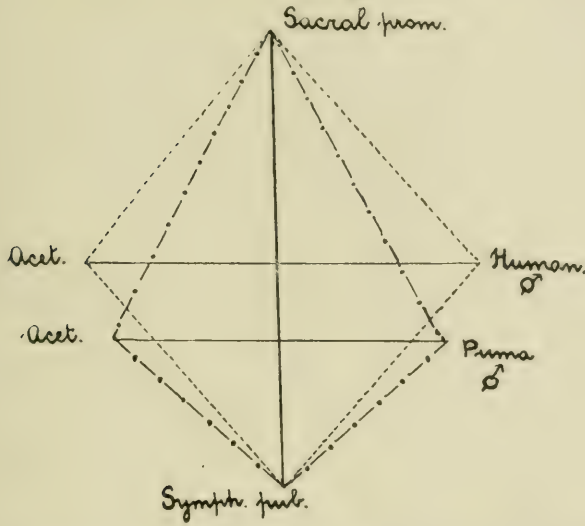


FIG. 1.—The pelvis of a human ♂ has been drawn to a definite scale, and drawn to the same scale the pelvis of a puma ♂ has been super-imposed. Note the amount of divergence of the cotylo-sacral lines depends on the position of the inter-acetabular diameter.

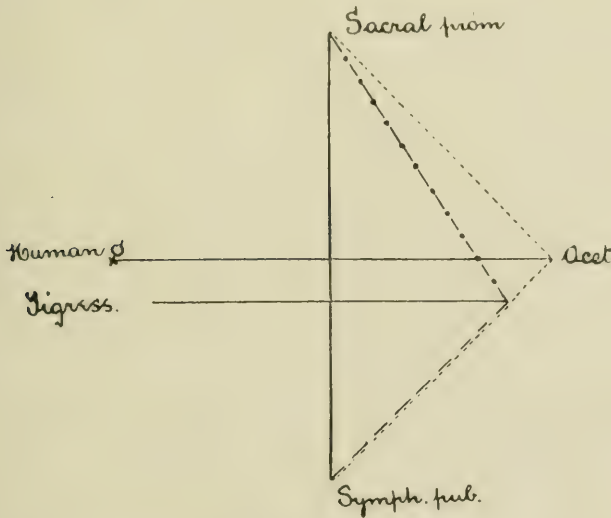


FIG. 2.—Comparison of pelvis of human ♀ and tigress, as in fig. 1.



in the transverse towards and greater than the antero-posterior pelvic diameter there is a greater divergence of the lines of weight-propagation from the vertebral column to the acetabula, and on this factor it is proposed that the length of the femoral neck is in direct ratio with the relative distance between the acetabula. In Table I. the measurements carried out and the methods of comparison adopted are fully explained, showing the interrelationship of the various pelvic measurements.

TABLE I.

	Ant.-post.	Post-acet.	Pre-acet.	Trans.	Index.
	cms.	cms.	cms.	cms.	
Ass . . . . .	14	9.2	4.8	10.4	134
Deer . . . . .	13.6	9.3	4.3	8.6	158
Sheep . . . . .	10.1	6.9	3.2	6.7	151
Deer . . . . .	7.1	5.0	2.1	4.4	161
Tigress . . . . .	9.7	5.7	4.0	7.2	134
Puma . . . . .	6.5	4.2	2.3	4.3	151
Cat . . . . .	3.5	2.2	1.3	2.7	130
Gazelle . . . . .	6.2	3.9	2.3	4.7	132
Goat . . . . .	6.2	4.1	2.1	4.2	147
Human (F.) . . . .	11.0	5.8	5.2	11.5	95

(Note the apes are excluded from this table.)

*Explanation.*—The antero-posterior diameter was measured in the usual way; the transverse is taken as the distance between the centre points of the acetabula on the pelvic aspect, which not being the greatest diameter makes the indices given higher than those usually stated. The post-acetabular length is that part of the antero-postular diameter which lies posterior to the transverse measurement, the pre-acetabular that part which lies in front. The pelvic index is calculated as usual.

To refer, though only in passing, to the pelvis as a weight-transmitting structure, it is evident from figs. 1, 2, and 3 what is meant by the relative shortening of the post-acetabular part of the antero-posterior diameter: because, the greater the transverse diameter, the nearer to the posterior boundary of the pelvis is that placed, while a narrow pelvis has that inter-acetabular measurement placed more anteriorly. This is as one would expect, the non-weight-bearing, though strain-resisting, anterior parts of the pelvis depending for their conformation on the weight-transmitting posterior parts.<sup>1</sup> Taking fig. 4 as representing two imaginary pelvises, a wide A-B, and a narrow A-C, then owing to the difference of divergence of the weight-transmitting lines, there will be a difference in the inclination to the vertical of the other component of that vertical force of which A-B

<sup>1</sup> For the mechanics of the pelvis reference may be made to Wood's article on the pelvis in Todd's *Encyc. of Anat.*, where, though not stated, the inference here drawn receives full support.

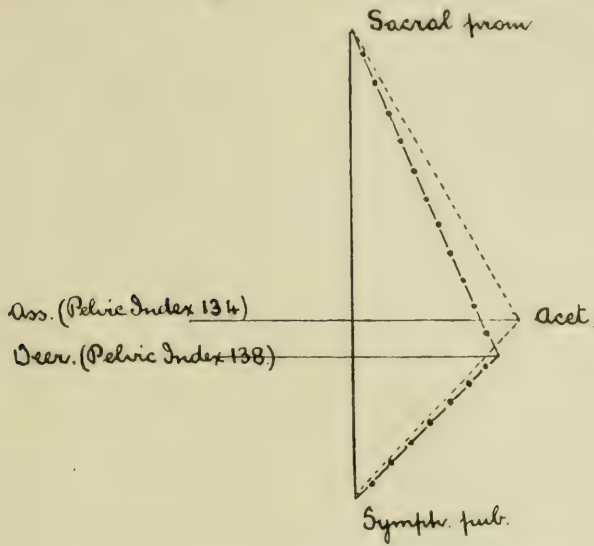


FIG. 3.—Comparison of pelves of ass and deer, as in fig. 1.

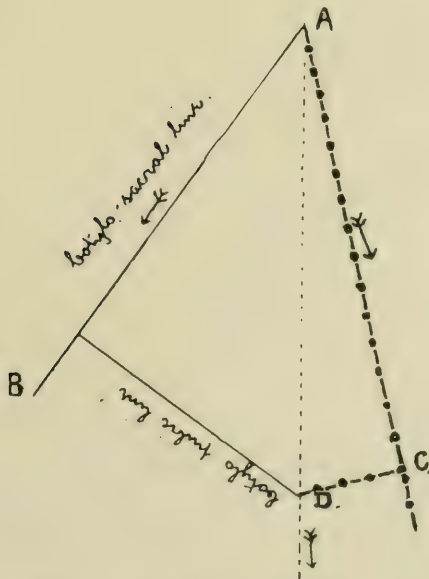


FIG. 4.—To show the effect of the amount of divergence of the weight-transmission lines on the conformation of the anterior parts of the pelvis.

or A-C' forms the actual transmission line, and, the more vertical the one component, then the more horizontal will that other component be, but the angle between the two components should, mathematically, remain a constant. Thus a narrow pelvis requires a long post-acetabular as compared with the pre-acetabular part of the antero-posterior diameter; and as the pelvis broadens, the further back will the transverse diameter be placed. In Table II. results on this point are tabulated for the human subject, and fig. 5 is drawn to scale to represent graphically the variations occurring in the adult human subject as regards the pelvic measurements.

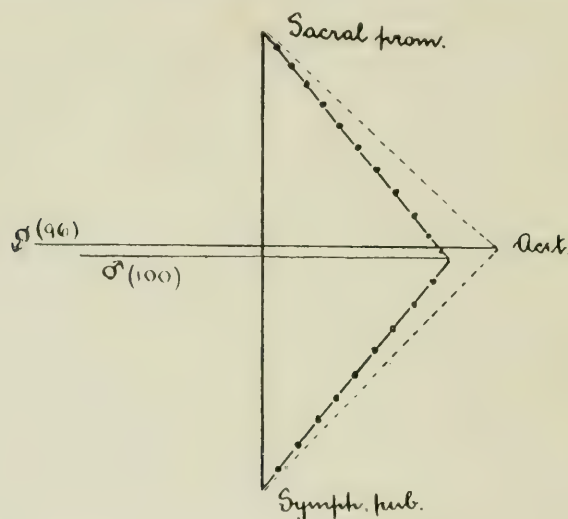


FIG. 5.—Comparison of human ♂ and ♀ pelvises, as in fig. 1. The numerals in brackets are the respective pelvic indices.

TABLE II.

	Ant.-post.	Post-acet.	Pre-acet.	Trans.	Index.
	cms.	cms.	cms.	cms.	
Human (M.) . . . .	9.6	3.9	5.7	10.7	90
" " " " " "	11.8	5.8	6.0	11.7	100
" " " " " "	10.3	5.4	4.9	10.8	95
" " " " " "	9.9	5.0	4.9	10.4	95
" (F.) " " " "	11.8	5.8	6.0	13.0	91
" " " " " "	12.0	6.4	5.6	12.5	96
" " " " " "	11.0	5.8	5.2	11.5	95
" " " " " "	12.4	6.3	6.1	13.1	94

*Explanation.*—The various measurements of this table are taken exactly as laid down in the explanation to Table I.

This difference of degree to the horizontal of the pelvic weight-bearing lines of pelvis of differing widths will mean a difference in the amount of resolution necessary in order to convert this oblique force into the required vertical from the acetabula to the ground: for, as is shown in fig. 6, the wide pelvis A-A will require a greater amount of conversion of its weight-

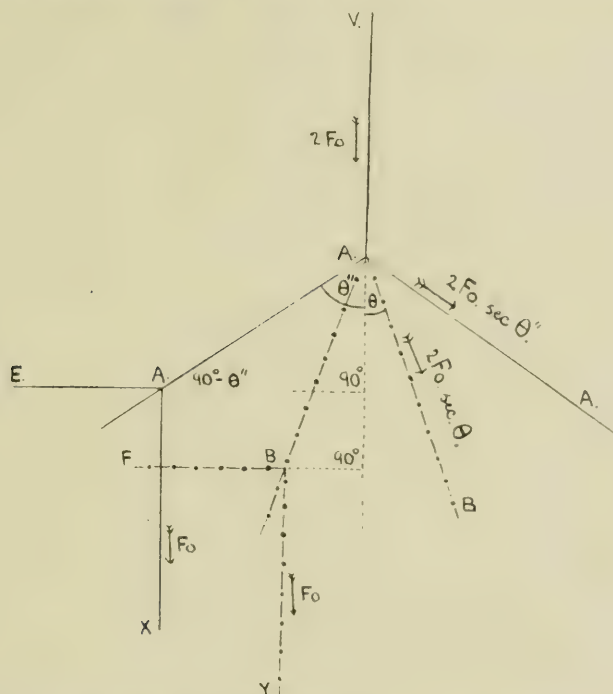


FIG. 6.—To show that the amount of divergence of the pelvic weight-transmitting lines influences the resolution of the oblique pelvic force into the vertical limb force.

Force acting along	VA=2 Fo.
"	AA=2 Fo. sec. $\theta$ ."
"	AB=2 Fo. sec. $\theta$ .
"	AE=2 Fo. tan. $\theta$ ."
"	BF=2 Fo. tan. $\theta$ .

But  $\theta < \theta'' < 90^\circ$ .  
 $\therefore \tan \theta'' > \tan \theta$ .

*I.e.* force acting along AE > force acting along BF.

bearing line A-A into the vertical A-X than will the narrow pelvis A-B into B-Y, always considering, as is here done, that the force acting in the horizontal plane is in all cases approximately relatively a constant. This is still more evident if the two lines A-A and A-B be resolved into their component forces, one of which is vertical, when, as is shown in fig. 6, a



greater amount of pure horizontal force must in the wider pelvis be converted into pure vertical force. On translation of the effects of this factor to the femora, it will in the first place be recognised that, though the sacro-iliac articulation has modified, yet the greater modification rests with the femur. The form of transmission of this oblique into the vertically acting force, which in nature has been adopted in the femur, is from the curved to the

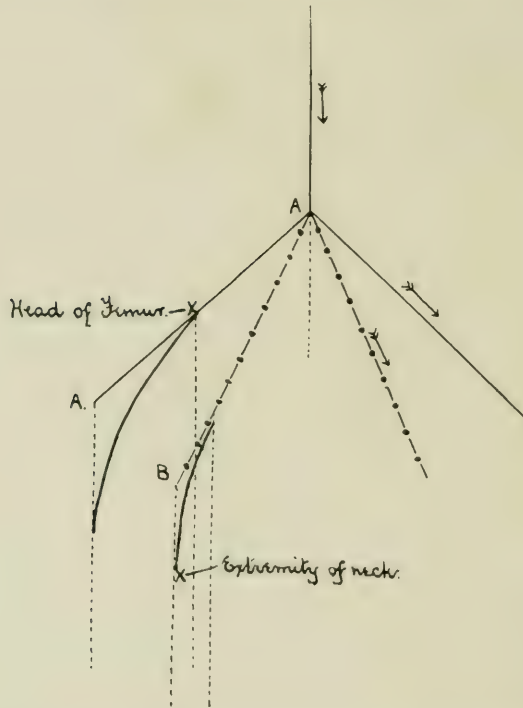


FIG. 7.—The transmission of the oblique pelvic force by means of a curve to the perpendicular. The arcs at A and B are of equal radii.

angular, the curved portion being at the upper end of the bone, with of course the concavity inwards. Now the economic organic tissue reaction is a factor relatively of the same degree throughout the whole animal series: and when this is combined with the simple mechanical fact that in a support of uniform curve and constant strength the greater the approximation of the two opposing forces the longer is the arc required, it will be clear that to compensate the increase of pelvic breadth there must be elongation of the femoral neck. In fig. 7 arcs of the same radius have been made to transmit the oblique force at the femoral head in a curve

from the head to the vertical; and as forces acting along a curve act tangentially to that curve, it is shown graphically that the distance from the femoral head to the point where the force acting tangentially on the curve is purely vertical is in the wider pelvis a longer distance than in the narrow pelvis. Thus, taking the "mechanical axis" of the lower limb—that is, the line of weight-transmission, which, joining the centre of the head with the centre of the knee, passes, when prolonged, through the centre of the ankle-joint—taking this as a vertical constant throughout the whole mammalian series, the greater the divergence of the lines of weight-propagation of the pelvis (that is, the greater the ratio of the pelvic transverse to the post-acetabular part of the antero-posterior measurement), the longer will the neck of the femur require to be.<sup>1</sup> It may be objected that the mechanical axis of the lower limb is not, in the human subject at least, a vertical quantity, but is inclined to the vertical. The amount of this inclination is small, exists only in the uncomfortable military position of "attention" to the extent of 3°.<sup>2</sup> and, inclined as it is to the perpendicular rather than away from it, the result would be not to lessen the length of the neck, but actually to increase it. In Table III. a series of measurements on this point is given, and the methods adopted fully explained.

TABLE III.

	Length of Neck.	Pelvic Trans.	Pelvic Index.	N.-T. Index.
	cms.	cms.		
Tigress . . . .	2.6	7.2	134	36
Puma . . . . .	1.5	4.3	151	37
Human (M.) . . .	4.1	11.0	95	37
Human (F.) . . .	4.4	12.5	94	36
Deer . . . . .	3.1	8.6	158	36

Note the constancy within limits of the neck-transverse index of pelves of widely differing pelvic indices. Though the neck has such a definite relation to the pelvic transverse width, the length of the shaft, of course, is not proportional to the length of the neck.

*Explanation.*—The length of the neck was taken as the distance from the point of intersection of the axes of the shaft and of the neck to the "base-line" of the head, in the axis of the neck. The axis of the shaft is taken as that line which, extending through the centre of the bone, if prolonged downwards would bisect the intercondylar line at the lower end of the femur. The axis of the neck is that line lying in the centre of the neck which bisects, though not at right angles, the "base-line" of the head. This base-line of the head joins the margin of the articular cartilage at the highest point on the neck with the margin at the lowest point, these

<sup>1</sup> Under investigation at the present time by the writer is the question of the reduction of the length of the neck of the human humerus as compared with the neck of lower forms.

<sup>2</sup> Fick, *Handb. d. Anat. u. Mech. d. Gelenke*, Bd. iii., S. 525.

being the two most fixed points obtainable.<sup>1</sup> Tracings of each bone examined were made from the anterior aspect by means of the dioptograph, and the measurements obtained from the projected diagram, which was always of the same dimensions as the original bone. This method was adopted in preference to any other, on account of being the one of smallest possible error, no external measurement being found which was in the least degree accurate. The neck-transverse index (N.-T. index) is calculated thus:—

$$\frac{\text{Length of neck}}{\text{pelvic trans.}} \times 100.$$

Even in the human subject there is evidence of the greater length of the femoral neck of the broader pelvis of the female as compared with the male. Cruveilhier,<sup>2</sup> Hyrtl,<sup>3</sup> and others are all agreed on this point; and though Bertaux<sup>4</sup> found that the neck of the female femur was less than that of the male, and the right neck shorter than the left, yet his absolute accuracy may be doubted, as it is evident from the actual measurements given that some external method of determining the length of the neck was adopted. Sue<sup>5</sup> found the femoral neck "a few lines longer" in the female than in the male. In the present series of bones examined, fifteen male and fifteen female (Table IV.), notwithstanding the relative shortness of the female femur, it was found that the neck was on an average 3 mm. longer than in the male; but individually an enormous variation is present, which variation does not coincide with the length of the femur, nor with the angle between the neck and the shaft.

In tracing the developmental changes in the length of the neck of the femur in the human subject, it is well known that the human foetus is simian in this respect—that is, the neck relatively to the adult condition is ill developed. On examination of the pelvis at this foetal stage, though it has been shown by Thomson<sup>6</sup> that sexual characteristics are already present at the fourth month, according to Duckworth<sup>7</sup> the pelvic indices are, for the female 82.4, and for the male 83.6 at this period. Thus, associated with a simian pelvis is a simian femur. There is, however, another factor to be considered as causative. As well as the mechanical force there is another force—a developmental one—found to be a determining factor in the production of the form, length, etc., of the osseous skeleton. But with a normal relationship between the mechanical forces and the

<sup>1</sup> This does not correspond with what is termed by Hoffa the base-line, for his limitation is "that line parallel to the acetabular outlet which passes through the base of the cartilage of the head."

<sup>2</sup> Cruveilhier, *Anat. Descrip.*, tome i. p. 231.

<sup>3</sup> Hyrtl, *Anat. d. Mensch.*, S. 409.

<sup>4</sup> Bertaux, *L'humérus et le fémur* (from Poirier).

<sup>5</sup> Sue, quoted by Humphry, *Human Skeleton*, p. 469.

<sup>6</sup> Thomson, *Jour. Anat. and Phys.*, vol. xxiii. p. 59.

<sup>7</sup> Duckworth, *Anthropology*, p. 296.

TABLE IV.  
*Measurements of human femur, per dioplograph.*

	Length of Femur.	Neck.	Angle.
	cms.	cms.	°
1. F. . . . .	38·9	4·5	129
2. M. . . . .	42·8	4·2	120
3. M. . . . .	40·7	3·3	118
4. F. . . . .	43·4	4·9	126
5. M. . . . .	45·4	4·2	129
6. F. . . . .	44·5	4·3	140
7. M. . . . .	45·7	4·3	124
8. F. . . . .	45·2	4·7	136
9. M. . . . .	44·1	2·9	123
10. M. . . . .	47·1	4·5	123
11. M. . . . .	46·8	3·9	120
12. F. . . . .	39·7	4·5	120
13. F. . . . .	41·0	4·7	116
14. F. . . . .	44·3	4·9	142
15. F. . . . .	40·0	3·9	128
16. M. . . . .	44·7	3·4	126
17. F. . . . .	44·5	4·3	137
18. F. . . . .	45·3	5·1	130
19. F. . . . .	40·7	4·2	119
20. M. . . . .	45·6	4·6	122
21. M. . . . .	43·7	4·7	126
22. M. . . . .	47·6	4·9	135
23. M. . . . .	45·6	4·0	132
24. M. . . . .	43·8	4·0	137
25. M. . . . .	46·7	4·2	113
26. M. . . . .	43·2	3·8	123
27. F. . . . .	37·6	4·0	124
28. F. . . . .	41·4	4·3	125
29. F. . . . .	43·9	4·0	122
30. F. . . . .	41·1	3·5	120

	cms.
Average length of male femur . . . . .	—44·2
„ „ female „ . . . . .	—42·1
Average length of male neck . . . . .	—4·1
„ „ female „ . . . . .	—4·4
Average male angle . . . . .	—125
„ female „ . . . . .	—127

*Explanation.*—The length of the neck was obtained as given under Table III., while the angle is taken as between the axis of the neck and the axis of the shaft. The length of the femur is taken as the “mechanical length”—that is, the condyles are placed on a transverse plane and the measurement taken to the head; this, of course, is not the greatest femoral length. Hepburn's osteometric board was used.

developmental forces, the former will serve as a guiding stimulus whereby the latter may most effectively execute the necessary modifications in the different parts of the osseous framework. The converse of this relationship is also true, that whenever there is a disturbance of this relationship there



will be anomaly of form. The disturbance may be in either of two directions, in both cases passing towards complete suppression; for the mechanical may be diminished or suppressed, with the non-control of, or absence of stimulus to, the developmental, a condition leading towards anomalies of form which will be of the embryonic or the primitive type. Or, on the other hand, there may be preponderance, complete or partial, of the mechanical over the developmental, where the anomalies would tend to be progressive, and emphasised at the points of greatest strain. As regards the application of the former to the lower limbs, it would in the adult be found only in such conditions where from abnormal causes the femur has not been required to transmit the weight of the body—for example, in an early complete paralysis, in an early amputation, in extreme hydrocephalus, etc. In the foetus the developmental force will be in preponderance over the mechanical: that is, the absence of the weight-transmission of the body will connote an absence of those mechanical factors producing the changes which are so typical in the growing human subject—an increase of the length of the neck of the femur. Thus the absence of the correlation between the mechanical and the developmental forces in the direction of the suppression of the mechanical will in itself constitute a reason as to the shortness of the neck of the foetal femur. In Table V. there is a tabulation of the measurements of the neck at different ages, showing the relatively great increase once the mechanical strain is brought to bear on the tissues of the neck.

TABLE V.

Age.	Length of Neck.	Length of Femur.	N.-F. Index.
	cms. (av.).	cms. (av.).	
Adult, F. . . . .	4.4	42.1	10.2
„ M. . . . .	4.1	44.2	9.7
Years, 18 . . . . .	4.2	44.4	9.6
„ 16 . . . . .	3.9	40.6	9.6
„ 14 . . . . .	3.5	37.6	9.2
„ 10 . . . . .	2.7	34.4	7.8
„ 8 . . . . .	1.7	25.2	6.7
„ 5 . . . . .	1.1	17.2	6.4
„ 4 . . . . .	.9	14.7	6.1
„ 2 . . . . .	.6	11.6	5.2
At birth, . . . . .	(.4 ?)	9.4	4.3
Fœtus, 5 months . . . . .	(.2 ?)	4.3	4.6

*Explanation.*—All the measurements were carried out as before. The neck-femur (N.-F.) index cannot be held as of much value apart from the purposes of comparison. It is taken thus:—

$$\frac{\text{Length of neck}}{\text{Length of femur}} \times .00.$$

It will be noted from the table that there is a steady increase in the relative length of the neck up to the age of 10-14 years, at which period



FIG. 8.

the neck of the femur may be said to have reached its maximum ontogenetic length, in the relative sense. Thus it must be evident that, to have any appreciable effect on the length of the neck of the femur in the direction of

non-elongation, the mechanical forces must have been absent from a comparatively early period, though this is presupposing that retrogression cannot take place. I have been able to examine two skeletons in this



FIG. 9.

respect. In skeleton 1 there has been hip-joint disease from an early period, so that the left leg is over all 12 cms. shorter than the right (fig. 8). In comparing the upper ends of the femora, it is more than interesting to note the relatively short neck and the relatively large angle of the diseased



FIG. 10.





FIG. 11.

side (fig. 9). Absolute measurements were not possible, but those given are at least approximate.

				Length of Femur.	Neck.	Angle.
				cms.	cms.	
Healthy limb	.	.	.	34·7	3·1	125
Diseased limb	.	.	.	27·5	1·9	140

In skeleton 2 the first glance at the femora is sufficient to indicate that they could not possibly have borne the weight of the body, and here again

the neck of the femur and the angle are of the embryonic type (figs. 10 and 11). The approximate measurements are:—

	Length of Femur.	Neck.	Angle.
	cms.	cms.	
Right limb . . . . .	33·9	(2·0 ?)	(140 ?)
Left limb . . . . .	35·1	2·1	135

The other possibility—that is, where there is a preponderance of the mechanical over the developmental forces—is illustrated in the condition of rachitis. Here, from pathological causes, the developmental forces cannot take their proper place in the production of the form of the bone. Thus, apart from an association with an increase absolute and relative of the



FIG. 12. — Rachitic femur. Physiological elongation of the neck.



FIG. 13 — Rachitic femur. Physiological elongation of the neck.

pelvic transverse diameter, the rachitic femur undergoes, concomitant with the increase of its anterior curve, a curving outwards of its upper part, or in other cases a curving inwards of its lower part, more commonly the former. That is, as is shown in figs. 12 and 13, the femoral neck, the curved weight-transmitting line from the head to the vertical, has spread far past its normal limit, and may here be said, physiologically rather

than anatomically of course, to extend from the head past the middle of the shaft.

It may be objected that no account has been taken of another acting force, the muscular force or muscular pull, which by many authors is spoken of as moulding the whole osseous skeleton. Muscular force is, however, a modifying rather than a controlling factor, and will never under normal conditions act in a manner to control or divert the action of the mechanical force. Muscular force is thus simply the dynamic expression of those factors which under normal conditions—that is, with a normally acting mechanical force—temporarily rather than permanently bring about and sustain, in the new direction of the line of force, modifications of the direction of the normal line of action of the mechanical force. Through the continued action in one constant direction, it may be that a local modification in the form, contour, size, etc., will be produced, but never will a normal muscular force control or divert the normal mechanical force. This expression of the influence of muscular force does not in the least detract from what is known as “Wolf’s law,” wherein it is held “that the shape of the bones is determined by the conditions of reaction to body weight, and the stress and strain of muscular action.”

2. *The Angle of the Neck of the Femur.*—The angle of the neck of the femur, often referred to as “the angle of inclination,” is here understood as the medially open angle between the axis of the neck and the axis of the shaft. According to the generally accepted yet somewhat diverse statements of different authors, this angle varies throughout the mammalian series, and in man it varies with the age and with the sex. The conclusions of Humphry<sup>1</sup> in regard to this point, those which have become classic, are:—

- (1) The angle varies at any given age.
- (2) It is smaller in short bones than in long: most likely to be small when the pelvis is wide: the combination of these two usually rendering it smaller in women than in men.
- (3) It decreases during the period of growth, but after growth is completed there is no change.
- (4) If the limb be relieved of its weight during growth, the angle remains open, or may become wider.

Deductions such as these could not be improved on as bases on which to institute an inquiry into this question—the amount of divergence between the two components of the femur.

In his second conclusion Humphry states that “the angle of the neck of the femur is most likely to be small when the pelvis is wide.” From

<sup>1</sup> Humphry, “The Angle of the Neck of the Femur,” *Jour. Anat. and Phys.*, vol. xxiii.

this it would of necessity follow that the angle is most likely to be great when the pelvis is narrow. That the angle looks as if it would be smaller in the wider pelvis, one would at a first glance deduce from fig. 7. If, however, these diagrams are read, as they are drawn, in the truly mechanical sense, it will be seen that this cannot possibly be the case, and especially if a resolution is made as in fig. 14. Where, if in the two pelvises

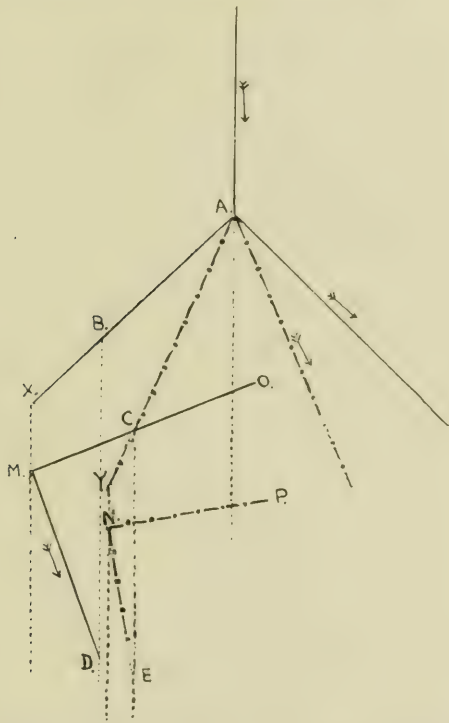


FIG. 14.—To show that the angle of the neck of the femur tends to remain a constant (see text).

A-B and A-C the respective lengths of the necks of the femora be B-X and C-Y, or some lines running between the verticals at B and X and C and Y, with, of course, the neck of greater length in the wider pelvis, then it is obvious that the inclination of the shaft from the extremity of the neck back to the vertical at the knee will always vary according to the length given to the shaft. Now, the deviation from the vertical of the shaft, and in consequence its length, will not be determined by purely mechanical causes, but these will be influenced by other factors, develop-



mental and physiological in the main: yet the less deviation there is, the more economic will be the organisation required, made compatible, of course, with a structure which is convenient for purposes other than mere stability. But the application of the same laws to both pelves, the narrow and the wide, with their respectively short and long femoral necks, will always result in the tendency to a greater proportional length of the femur of the latter pelvis. Now, it is to be noted that this proportional length is not in direct ratio to the length of the neck; for example, in one species if the neck of the femur be twice as long as in a second species, it does not follow that the shaft of the former femur will be twice as long as the shaft of the latter. The connation is only that the shaft of the former will tend to be longer than the shaft of the latter. On this fact rests the reason as to the greater inclination of the femur of the broader pelvis. Now, in fig. 14, if the vertical forces acting along D-B and E-C have as one of their components the femur shafts D-M and E-N in their proportional lengths, then it is correct to state that, though the other components may have a varying direction to the walls of the pelves as expressed by the sacro-acetabular lines, or by the antero-posterior pelvic diameters, yet the angle between the two components will remain a constant. That is, that, *per se*, the width of the pelvis should *not* in the slightest degree influence the amount of divergence between the axis of the neck and the axis of the shaft; what does follow is the difference in the obliquity of the neck of the femur. This tendency to the constancy of the angle of the neck of the femur is borne out in Table VI., where, within limits, the angle remains a constant for the adult.

TABLE VI.

	Pelvic Index.	Angle.
	(Av)	
Human (F.) . . . .	94	127
" (M.) . . . .	95	123
Gorilla . . . . .	147	120 (Duckworth gives 124°).
Tigress . . . . .	134	123
Ass . . . . .	131	127
Deer . . . . .	158	125
Puma . . . . .	151	128

*Explanation.*—All these measurements have been detailed before. Fig. 15 shows how various measurements are taken.

(*N.B.*—It is a significant fact that the angle which the morphological neck of the humerus makes with the shaft of the bone is in the human subject 125–130°.)

In application of this constancy to the adult human subject, Humphry's first conclusion, "that the angle varies at any given age," is only too evident. In Humphry's series there was a range of degree from  $113^{\circ}$  to  $136^{\circ}$ , other writers, as a rule, admitting a similar variation. It is obvious that this

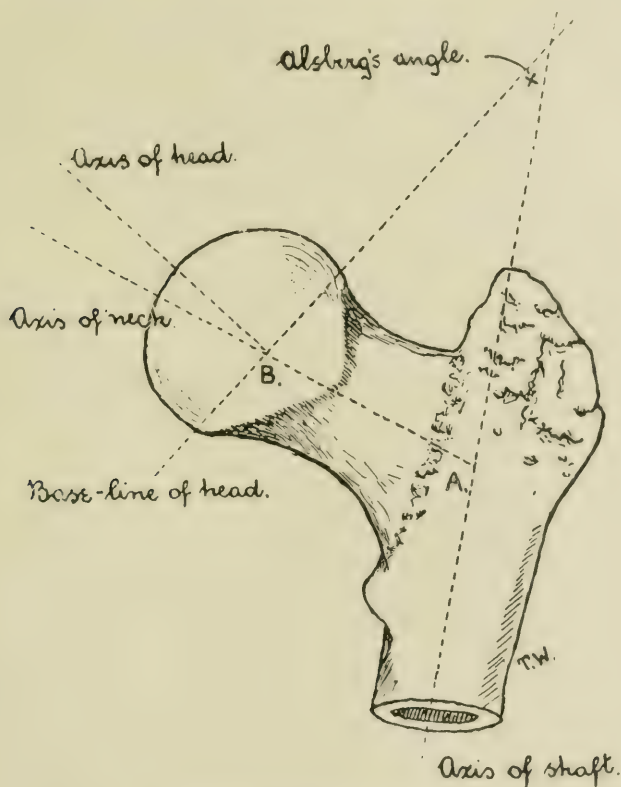


FIG. 15.—To show how various measurements are obtained.

Angle at A is angle of neck of femur; A-B is length of neck of femur.

variation is purely individual, and is of much greater extent than that found between the average of man and other mammals. Individually there is variation in the breadth of the pelvis (Table II.), in the length of the neck, and in the length of the shaft (Table IV.), but these variations can in no possible manner be correlated to the variations of the angle.<sup>1</sup> The

<sup>1</sup> Hirsch (*Anat. Hefte*, Bd. xxxvii.) puts forward the view that a long neck is associated with a large angle. The same author (*op. cit.*, 1899, S. 10) correlates the angle and the area of the transverse section of the shaft.

causes must be assigned to differences in individual developmental reaction, causes which can never lend themselves to proof.

Now, as regards the sexual variations which are said to exist in respect to this angle, Humphry has summed up the accepted view in his conclusion, "that in short bones the angle tends to be small, and it is most likely to be small when the pelvis is wide." Both of these statements, even in their limited application to the human subject, are founded on the idea that the femur will be developmentally plastic, but the inclination of the neck to the horizontal has been considered as remaining absolutely fixed. That is, that the one factor which can be shown to vary Humphry has concluded to be unchangeable, and if this hypothesis were correct the angle would be smaller in the shorter femur of the female. But in view of what has already been proved, and in light of the results given in Table IV., the angle can in no sense be said to vary directly with the sex. In his work on this angle, Luschka<sup>1</sup> formulated the conclusion that the female angle was actually greater than that of the male; Hyrtl<sup>2</sup> describes the angle as being the same in both sexes; Charpy,<sup>3</sup> in his measurements at all ages and in both sexes, came to these conclusions: "The angle in the young person is greater than in the adult; in the adult it is the same for both sexes, on an average 127°; in the old person the angle is the same as for the adult." Parsons,<sup>4</sup> in a recent series of measurements of 300 bones, found the male angle as 126.5° and the female as 125.5°, and states as his conclusion, "that the angle of the neck is of no value as an indication of sex."

In the study of the ontogenetic changes of this angle there is universal proof that the divergence is greater in young children than in the adult, and greater in the fetus than in the child. This change in the angle of the growing bone—a decrease in degree concomitant with the increase in age—is dependent on the controlling influence of the mechanical over the developmental forces. By pure development the whole neck tends to be more or less directly vertical, or perhaps spiral; thus the open angle in the fetus, thus the open angle of the femur on which strain has never been put, *e.g.* Humphry's measurements in early amputations, paralysis, etc. Reference may also be made to skeletons 1 and 2 already described. On to this vertically directed neck there is transmitted through the head of the femur a shearing force, acting vertically, which is tending to produce an angle between the two components through which that vertical force is transmitted, and as a result of this there will be, not a bending of the osseous or cartilaginous tissues of the neck of the femur, but a difference

<sup>1</sup> Luschka, *Anat. d. Mensch.*, Bd. iii. S. 339.

<sup>2</sup> Hyrtl, *Anat.*, S. 409.

<sup>3</sup> Charpy, *Bull. de la Soc. d'Anthrop.* (Lyon), 1884.

<sup>4</sup> Parsons, "The English Thigh-bone," *Jour. Anat. and Phys.*, vol. xlviii. p. 260.

in the plane of the epiphyseal cartilage of the head. This epiphysis is horizontally placed in the foetal bone, and to assume the adult oblique position, there is, as it were, a greater amount of growth at the outer end than at the inner end of the plate.<sup>1</sup> (This point will be more fully dealt with later.)

Many authors also hold that there is a senile change—a further reduction of the adult angle. Against this change Humphry has written most conclusively, and on a series of measurements of senile bones bases the deduction “that there is no tendency for the angle to collapse in old people.” In other words, the mechanical and the developmental forces having acted up till the end of development in producing a structure best suited for the individual organism, there is, normally, no tendency for that structure to change. Substantiating Humphry’s dictum, there is the conclusion of Charpy, “in the old person the angle is the same as in the adult.” Ward,<sup>2</sup> writing on this supposed senile characteristic, says, “This change (the decrease of the senile angle) is not so constant as Cloquet<sup>3</sup> and other anatomists would seem to represent them: for on examining the thigh-bones of very old subjects in the dissecting-room, I have found many entirely free from the described peculiarities, and indistinguishable, in respect to form, from the femur of the well-formed adult.” Bell,<sup>4</sup> who first drew attention to the processes of interstitial absorption upon which these progressive metamorphoses depend, describes it not as a healthy action natural to the senile period of life, but rather as an abnormal process incident to a debilitated or otherwise morbid condition of the economy in particular individuals.

<sup>1</sup> There are authors who hold to the idea that the main factor in the reduction of the angle is the pull of the ilio-psoas muscle. It can only be at the most of minor importance, as is evident from those cases of amputation below the insertion of the muscle, where the angle is still found large (for cases, see Tubby, *Orthop. Surg.*, vol. i. p. 629).

<sup>2</sup> Ward, *Osteology*, p. 263.

<sup>3</sup> Cloquet, *Hum. Anat.* (1828), p. 142. (N.B.—This is not Cloquet the anatomist, as Ward leads one to believe, but H. Cloquet, Professor of Physics at Paris.)

<sup>4</sup> Bell, Benj., F.R.C.S. (Edin.), *Interstitial Absorption of the Neck of the Femur*, 1824.



(1) TWO CASES OF CERVICAL RIBS. (2) AN ANOMALOUS  
ARRANGEMENT OF THE VAGI. By M. F. LUCAS, M.B.,  
B.S., *Demonstrator in Anatomy, London (R.F.H.) School of  
Medicine for Women.*

TWO CASES OF CERVICAL RIBS.

IN the study of these two cases of cervical ribs, particular attention has been paid to the other costal and vertebral elements, and also to the constitution of the cervical, brachial, and lumbo-sacral plexuses.

Subject 1, female, presented bilateral cervical ribs; the left was 6 cm. long, and did not quite articulate with the 1st thoracic rib, but was attached to its medial border by a short band of fibrous tissue. On its upper surface were two grooves, the anterior very well marked and evidently produced by the lowest trunk of the brachial plexus, the posterior more shallow, formed and occupied by the middle trunk.

External and internal intercostal muscles were present, and also a well-marked scalenus minimus, arising from the tip of the cervical rib, and spreading out over the upper surface of the 1st thoracic rib. The sub-clavian artery just crossed the origin of this muscle, and thus lay below the lowest trunk of the plexus and on a more anterior plane (fig. 1).

The brachial plexus on this side received some fibres from the 4th cervical root directly, and also indirectly from the fibres of C 4 to the phrenic nerve. The 1st thoracic nerve sent a small branch to the normal 1st intercostal space, and also to the space between the cervical and 1st thoracic rib, before joining the 8th cervical nerve (see fig. 2).

On the right side the cervical rib was less well developed, measuring only  $2\frac{3}{4}$  cm. Its upper surface presented a groove for the middle trunk of the brachial plexus. The tip of the rib gave origin to a similar muscle to that described on the opposite side.

No communication was found between the 4th and 5th cervical nerve roots. The 1st thoracic nerve gave off branches to the normal 1st space and also to the highest, but the root of the 1st thoracic nerve joining C 8 was appreciably larger on this side than the other (see fig. 2).

The lumbar plexus was normal on both sides. The vertebral and other costal elements were also normal. The 12th thoracic ribs were fairly

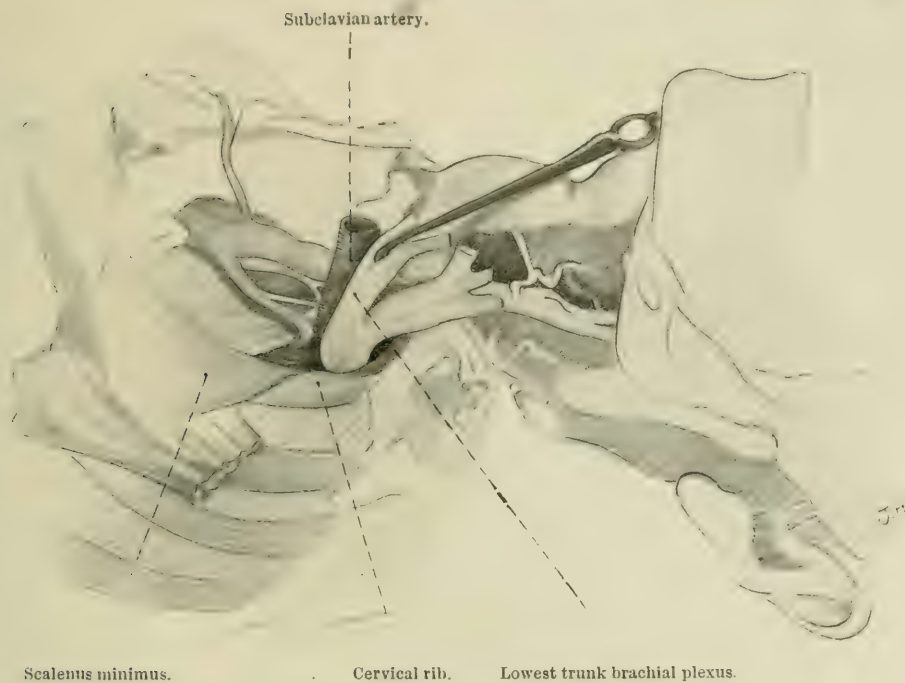


FIG. 1.—Dissection showing relations left cervical rib.

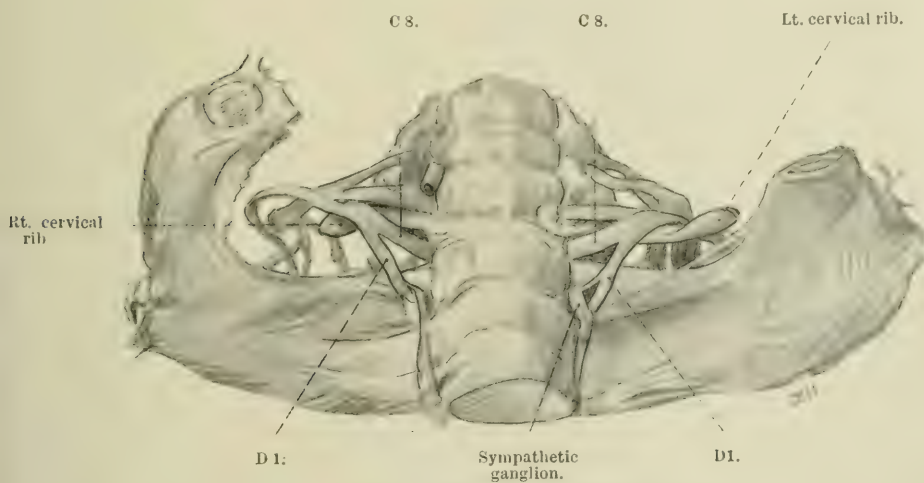


FIG. 2.—Course of 1st thoracic nerve.



came from L 1 and 2 on the left and L 2 only on the right. This prefixation of the lumbar plexus was associated with absence of the 12th thoracic ribs. The right and left transverse processes of the 12th thoracic vertebra measured 2.5 and 3 cm. respectively, and presented the appearance of normal 1st lumbar transverse processes. The 11th thoracic ribs were each 16 cm. long. Five lumbar vertebrae were present. The sacrum consisted of six pieces, having apparently assimilated a caudal element.

The 1st thoracic ribs of this subject presented no subclavian groove. The nerves of the brachial plexus and the subclavian arteries were kept

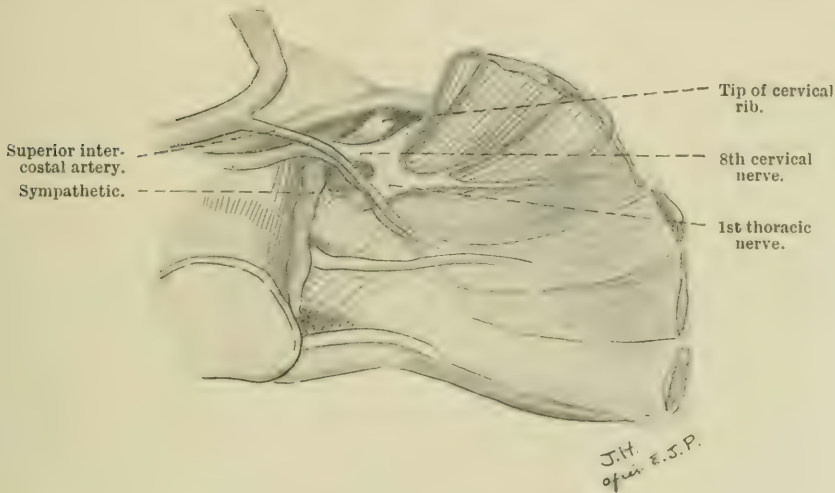


FIG. 4 (Subject 2).—Left side from below.

off from the rib by scalenus minimus muscles (see fig. 3). These latter muscles and the external intercostals produced a well-marked groove on the superior surfaces of these ribs: the groove running parallel with the inner borders of the rib, and extending as far forward as the attachment of scalenus anticus.

The points of interest in these dissections are the following:—

(1) In subject 1 the larger cervical rib is associated with a prefixed brachial plexus, the latter not only receiving fibres from C 4 root, but also receiving fewer fibres from T 1 than the plexus does on the opposite side, where the rib is less well developed.

(2) In subject 2, absence of the 12th thoracic ribs is associated with a cephalic movement of the lumbo-sacral plexuses.

These facts are in favour of there being a causal association between  
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the formation of limb plexuses and the development of costal elements. Further, from the study of these and other cases it seems probable that, as has already been suggested, (1) prefixation of the brachial plexus leads to the production of cervical ribs, and post-fixation to a deformed or abortive 1st rib; and also that prefixation of the lumbo-sacral plexus causes small or absent 12th thoracic ribs, and post-fixation in varying degrees leads to production of 1st lumbar ribs with corresponding degrees of development.

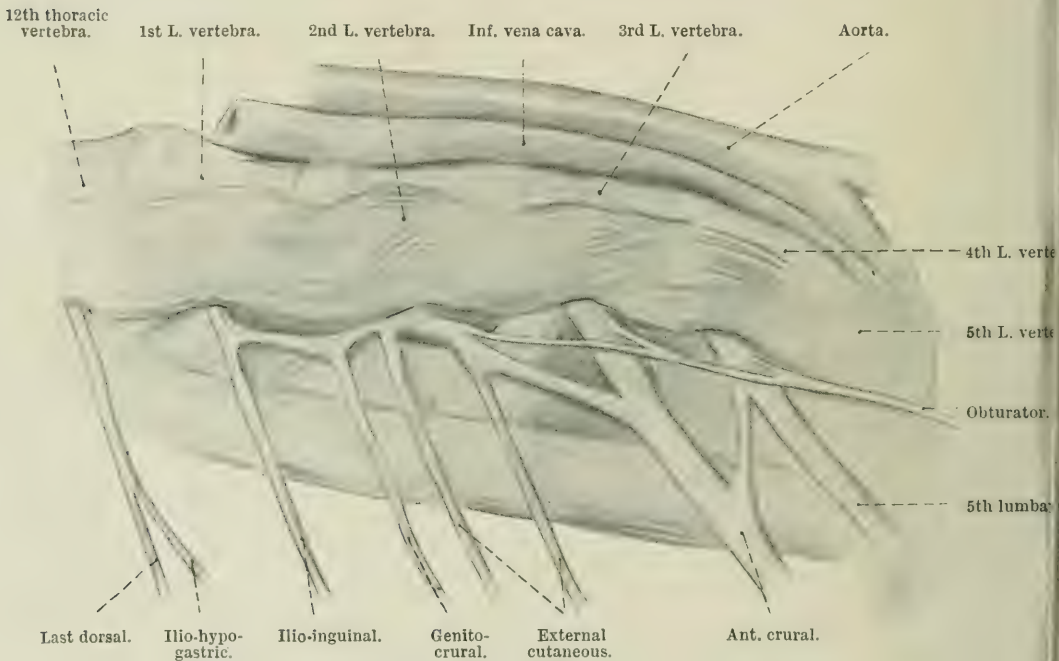


FIG. 5 (Subject 2).—Lumbar plexus.

The fact that the sacrum has assimilated a caudal element is anomalous, for the movement of the sacral elements is not usually opposed to the movement of the lumbo-sacral plexus.

With regard to the clinical aspect, it is conceivable that the conditions present in the first subject may have caused some symptoms, but in subject 2 the lowest trunk of the brachial plexus did not pass over the cervical rib on either side. No evidence of physical signs, referable to the rib condition, was found in either case, and no information as to symptoms could be obtained from notes on the cases, as both were mental.

I am greatly indebted to Miss Hardy and Miss Partridge for their drawings of the dissections.

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#### REFERENCE.

(1) WOOD JONES, F., *Jour. Anat. and Phys.*, vol. xlv., "On the Relation of the Limb Plexuses to the Ribs and Vertebral Column."

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#### AN ANOMALOUS ARRANGEMENT OF THE VAGI.

The photograph illustrates a very unusual arrangement of the vagi. The left nerve enters the abdomen behind the œsophagus, and the right anterior to the gut. The œsophageal plexus was formed by branches given off from both nerves.

Rt. vagus.

Rt. vagus.

Esophagus.

Aorta.

L. vagus.

Anomalous vagi.



Normally, the vagi dispose themselves in one of two ways when they emerge from the posterior pulmonary plexus:—

(1) Two large branches issue from the pulmonary plexus on either side, apply themselves to the sides of the œsophagus, and break up at once into an inextricable network of fibres which surrounds the gut. From this plexus two nerve trunks emerge, and the left passes anteriorly and the right posteriorly into the abdomen. This is the appearance usually described, but the following arrangement is equally common:—

(2) One trunk (or two which speedily unite) emerges from the pulmonary plexus on either side: the left takes up an anterior and the right a posterior position in reference to the gut. The plexus gulæ is then formed by numerous branches uniting the main trunks.

Wertheimer (1) found that these anastomoses presented a relatively constant arrangement. A large branch from the left nerve passed behind the œsophagus and joined the right nerve just above the diaphragm, and also less constantly a smaller branch passed from the right vagus to join the left vagus in front of the gut. It is generally accepted that the normal position of the vagi at the lower end of the œsophagus is due to the rotation of the stomach. The anomalous arrangement of the vagi in this specimen appears, at first glance, to be at variance with this theory; but the explanation suggested is, that the greater part of the fibres of the right and left vagi respectively run in these cross branches described by Wertheimer, so that after rotation of the stomach the main part of the fibres of the right nerve lie anterior and the main part of the left vagal fibres lie posterior to the gut.

It is therefore submitted that this arrangement of the vagi is only the result of a gross exaggeration of a fairly common condition, and is not incompatible with the theory of rotation of the stomach.

#### REFERENCE.

- (1) *Compt. rend. Soc. Biol.*, 1901, p. 832.

## ANATOMICAL NOTES.

THE INTERNAL MAMMARY ARTERY ARISING FROM THE THYROID AXIS. By Professor FAWCETT, *University of Bristol.*

This case, recorded by Professor Fawcett, is apparently a rare one. The artery arose some distance above the origin of the thyroid axis from the subclavian of the left side, and descended into the thorax in front of the left phrenic nerve. It gave off

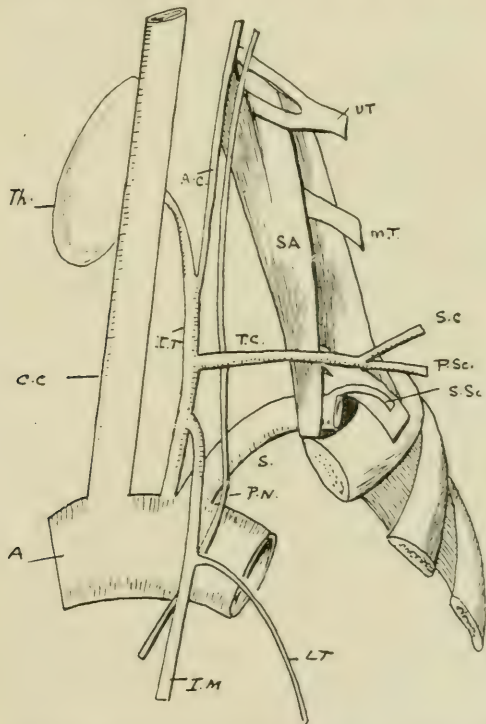


FIG. 1.—Internal mammary artery arising from the thyroid axis artery.

A., aorta; C.C., common carotid; A.C., ascending cervical artery; I.M., internal mammary; I.T., inf. thyroid; M.T., middle trunk brachial plexus; P.N., phrenic nerve; L.T., lateral thoracic branch of internal mammary; P.Sc., posterior scapular; S., subclavian artery; S.Sc., infrascapularis; U.T., upper trunk.

a large lateral thoracic branch on the medial aspect of the ribs. The suprascapular artery arose from the third part of the subclavian artery, and the constituent parts of the upper trunk of the brachial plexus perforated the scalenus anticus muscle.



PROFESSOR FAWCETT showed a specimen (the second he had seen) in which the EXTERNAL SEMILUNAR CARTILAGE was modified as in the illustration. It is a condition which apparently is comparatively rare, for Lick in Bardeleben's *Anatomy*

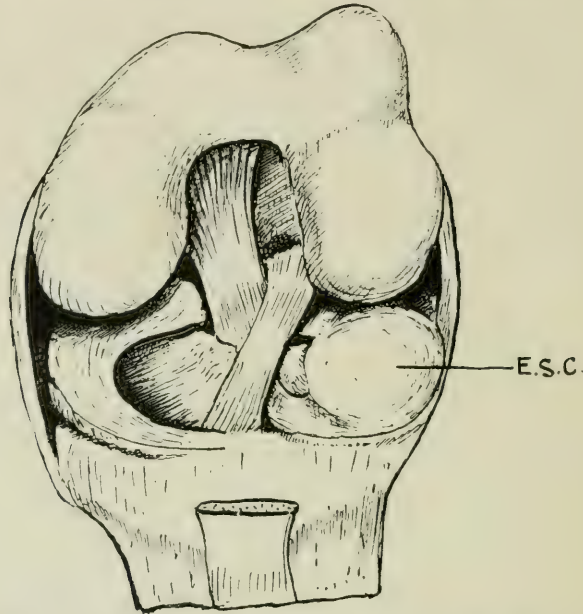


FIG. 2.—Drawing of left knee-joint opened from the front, to show complete circular, disc-like, external semilunar cartilage (E.S.C.).

records having seen one in which a foramen existed the size of a pea, and two cases are mentioned by Poirier, *Traité d'Anatomie*.

Professor Shaw states that Bruce Clarke saw three such cases in one limb.

In the specimen illustrated a strong posterior accessory band tied the hinder horn of the cartilage to the posterior aspect of the posterior crucial ligament.

# JOURNAL OF ANATOMY AND PHYSIOLOGY

THE CHARACTERS OF THE ENGLISH THIGH-BONE. PART II:  
THE DIFFICULTY OF SEXING. By F. G. PARSONS, *Professor  
of Anatomy, University of London.*

ON p. 238 of the 48th volume of the *Journal of Anatomy* I published a paper on "The Characters of the English Thigh-Bone," founded on the detailed examination of some 300 femurs from the great collection of bones beneath the church at Rothwell in Northamptonshire.

These bones, we have every reason to believe (see *Jour. R. Anthropol. Inst.*, vol. xl., 1910, p. 483), belonged to inhabitants of that town who died in the thirteenth, fourteenth, and fifteenth centuries, and I hoped, and still hope, that they may form a standard with which to compare other collections of thigh-bones.

As Dr Wood Jones accurately observed, in the discussion which followed the paper, a distinct though unavoidable source of weakness was the fact that the bones had been arbitrarily sexed by myself from previous experience gained in London dissecting rooms and museums, and it was too much to hope that in every case I had judged rightly.

For this reason it seemed necessary to examine a series of modern femurs, the sex and age of which were definitely known, in order

- (1) To see whether a group of sexual characteristics could be established.
- (2) To test these in order to prove how far they are reliable.
- (3) Having defined and tested the sexual characters, and having discovered my powers of accurate sexing, to review the sex of the Rothwell bones by their aid.
- (4) To compare the readjusted average measurements of the Rothwell bones with those of modern London dissecting-room subjects.

Unfortunately, the only femurs I could use for my comparison were those of our dissecting rooms, and they are open to three objections:

TABLE I.—MALE FEMURS FROM LONDON DISSECTING ROOMS.

No.	Height.	Age.	Max. Length.		Obl. Length.		Diam. of Head.		Width. Lower End.		Shaft. L. Diam.	Platymeria.				Angle of Neck.		Length of Neck.	
			R.	L.	R.	L.	R.	L.	R.	L.		Ant.	Post.	Transverse.	Index.	R.	L.	R.	L.
1	172.2	69	470	473	462	466	50	51	79	80	28	29	29	36	33	81	88	...	...
2	183.0	34	480	480	472	478	50	50	80	80	25	26	28	30	35	86	...	...	...
3	165.1	71	433	...	431	...	48	...	79	78	29	27	29	34	34	85	85	...	...
4	165.1	82	450	450	445	450	48	48	...	...	28	29	30	28	31	84	97	82	...
5	175.3	73	468	468	468	468	50	50	...	...	28	29	33	32	35	94	91	...	...
6	167.7	81	475	472	472	470	50	51	...	...	27	28	27	28	31	87	87	...	...
7	162.7	58	442	445	440	442	48	49	80	80	29	30	30	28	32	94	87	...	...
8	149.2	64	391	395	388	389	44	46	68	70	27	26	28	31	33	84	85	...	...
9	159.5	60	493	490	490	494	49	49	81	80	28	29	28	33	34	85	85	...	...
10	183.5	47	511	500	509	497	52	51	79	79	30	29	27	26	37	73	70	...	...
11	171.3	79	468	...	467	...	52	...	82	80	31	...	...	...	38	...	...	...	...
12	161.4	68	435	432	433	430	49	49	80	80	27	27	26	...	34	...	...	...	...
13	169.0	80	486	489	481	485	51	51	81	81	29	30	29	30	36	81	91	...	...
14	162.7	78	447	445	444	441	47	47	72	72	27	27	29	31	31	97	94	...	...
15	174.0	62	474	475	471	473	50	51	87	87	30	31	29	28	37	78	72	...	...
16	176.6	71	473	474	471	468	53	52	81	81	30	30	28	29	34	83	83	...	...
17	172.2	61	459	459	456	455	51	51	83	82	31	31	32	31	35	97	89	...	...
18	162.7	58	442	445	440	442	48	49	80	80	29	30	28	32	32	94	87	...	...
19	155.6	49	426	414	424	414	46	45	70	70	28	29	31	31	36	86	86	...	...
20	156.8	68	426	...	426	...	51	...	80	...	29	...	...	...	36	...	...	...	...
21	172.8	80	465	455	460	453	53	52	86	85	29	...	31	31	33	94	89	...	...
22	163.8	61	444	...	440	...	49	49	76	76	24	25	29	28	34	85	78	...	...
23	177.8	21	485	485	483	484	51	51	80	80	27	26	29	29	33	84	85	...	...
24	161.4	64	...	413	...	410	...	45	...	77	...	27	...	30	...	...	...	...	...
25	184.2	63	507	507	504	503	52	51	83	83	28	28	28	29	32	87	88	...	...
26	160.0	50	428	428	426	420	46	44	75	74	28	28	27	25	35	80	77	...	...
27	175.3	70	477	473	475	469	52	52	80	81	31	33	32	32	40	80	78	...	...
28	163.8	78	437	439	432	445	51	52	78	78	26	27	27	28	34	85	79	...	...
29	167.7	53	461	463	458	460	49	49	76	77	27	27	29	28	30	91	90	...	...
30	160.7	73	435	440	430	438	47	47	79	77	30	30	29	31	35	83	86	...	...
31	162.0	66	429	...	426	...	48	...	75	...	27	...	...	...	33	...	...	...	...
	167.6	64	456	455	452	452	49.5	49	79	79	28	28	29	29	34	85.5	85	...	...

## FEMALE FEMURS.

No.	Height.	Age.	Max. Length.		Obl. Length.		Diam. of Head.		Width. Lower End.		Shaft. L. Diam.	Platymeria.				Angle of Neck.		Length of Neck.	
			R.	L.	R.	L.	R.	L.	R.	L.		Ant.	Post.	Transverse.	Index.	R.	L.	R.	L.
1	164.0	48	434	436	430	434	44	44	71	71	28	29	27	28	30	90	93	...	...
2	147.3	79	396	398	393	395	45	43	70	71	26	26	24	24	34	82	71	...	...
3	149.8	70	437	434	434	435	42	41	...	...	27	27	24	24	33	73	73	...	...
4	143.0	48	364	364	360	361	41	41	62	62	23	24	25	24	28	90	86	...	...
5	148.7	63	411	413	407	410	43	43	64	66	23	24	23	22	31	81	74	...	...
6	160.0	62	429	430	428	429	47	47	78	75	28	29	27	26	34	85	80	...	...
7	158.8	69	425	426	422	423	44	45	73	73	26	27	29	28	35	88	78	...	...
8	167.5	67	437	434	433	431	46	46	71	71	27	27	27	27	34	80	82	...	...
9	156.0	67	420	415	413	412	44	43	74	75	25	27	26	24	31	29	84	...	...
10	162.6	81	428	422	425	417	...	46	75	75	29	29	25	24	41	61	59	...	...
11	164.0	36	442	445	438	441	40	39	67	67	23	24	26	26	28	93	93	...	...
12	147.4	70	398	404	395	399	41	39	69	68	25	25	23	23	31	81	74	...	...
13	151.0	79	379	...	376	...	40	...	62	...	25	...	...	...	29	...	...	...	...
14	162.2	78	417	417	413	413	45	45	72	...	28	...	31	...	34	...	...	...	...

firstly, that their possessors were for the most part aged people (their average age was 64); secondly, that they were the derelicts of the London poor, coming as they did in nearly equal proportions from the Poor Law Infirmarys and Pauper Lunatic Asylums; thirdly, that the number of bones which could be preserved intact for measuring was necessarily limited, and, as far as the females go, probably not numerous enough to give very reliable statistics.

An examination of the accompanying tables will show that my data consist of measurements of 31 male and 14 female subjects, taken in the dissecting rooms of St Thomas's and Guy's Hospitals. The average height of the males was 5 feet 6 inches and of the females 5 feet 1 inch, and I first propose to consider how far the advanced age of my material is likely to affect any general conclusions drawn from it.

It is clear that the age changes in the femur will chiefly affect the proportion which it bears to the stature.

If the average maximal length of all the male femurs be taken and 3 mm. deducted for the cartilage, because they were examined in the recent state, the result is 453 mm.; and Pearson's formula (*Phil. Trans.*, vol. xcii. p. 244), which was founded on observations of people who had died before senile changes began, gives a stature of 167 cm. as corresponding to this length. As the actual stature of the men from whom the present femurs were taken averaged 5 feet 6 inches, or 167.6 cm., it does not look as if there were any serious error as far as the males are concerned.

With the females, on the other hand, there is 4 cm. wanting in actual stature when compared with the stature to which their femurs entitle them under Pearson's formula, and for this reason and their small number I am quite ready to agree that the results obtained from them are not likely to be as satisfactory as are those obtained from the men.

#### THE SELECTION OF SEXUAL TESTS.

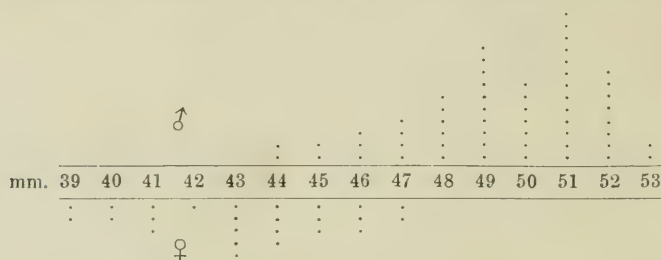
My next attempt will be to select a certain number of measurements which seem either beyond the overlap of the range of variation in the two sexes, or are at least so near the margin as shall make it extremely likely that the right sex is indicated.

Taking the vertical diameter of the head of the femur, it will be noticed that in the tables there are 82 records (57♂ and 25♀), and the mean between the average of the two sexes is 46 mm. with the cartilage in position. If we were to take this 46 as the border line on which the sex could not be told, and all cases above 46 as male, and all below as female, we should be right 70 times (85 per cent.), wrong 6 times (7 per cent.),



while 6 cases (8 per cent.) would fall on the border line and therefore could not be determined.

TABLE II.—DIAMETERS OF MALE AND FEMALE FEMUR HEADS.



If we look at the accompanying curve (Table II.), it will be evident that a certain proportion of male femur heads are less than 46 mm., and a certain small proportion of females more than 46. In this small series no females were over 47; but Dwight, who published a series of 200 measurements of each sex,<sup>1</sup> shows that in American women of white ancestry 48, and even as much as 51, may rarely occur, while on the other side the male bone may sink as low as 42. I do not propose to notice these extreme cases, but I think that for practical purposes all English femurs the heads of which, with the cartilage on, measure between 44 and 48 mm. inclusive, should be submitted to further scrutiny.

I have satisfied myself that, when the blades of the calipers are held parallel to the long axis of the neck, as in fig. 1, the cartilage occupies more than 1, but less than 2, mm. A subtraction of 1 mm. for absence of cartilage seems, on the whole, to give the fairest results. The figure also indicates how easily the measurements may be affected by tilting the blades of the calipers.

Having decided that all English femurs with heads above 48 mm. may be put on one side as males, and all with heads of less than 44 mm. as females, to what further tests shall the intermediate bones be submitted?

*The Length-head Index.*—It is constantly stated that the head of the female femur is not only actually smaller than that of the male, but smaller relatively to the length of the femur.

In order to test this, I divided the maximal lengths of all the male and female femurs into the vertical diameter of the head. In the males I found that the average index thus obtained was 109, while in the females it was 104. This appeared at first a hopeful clue to the sex, but I soon found

<sup>1</sup> *American Journ. of Anat.*, vol. iv. No. 1, pp. 19-31.



It is clear from the accompanying table that indices between 104 and 109 would give little help in sexing, but the chances of a bone with an index over 109 being male, and one under 104 being female, are very great. I admit, however, that the number of female observations is not large enough to justify anything more than a tentative suggestion, and the test is one upon which too much value should not be placed except in extremely marked cases.

*The Width of the Lower End.*—If the upper extremity is of great value in sexing, it is possible that the width of the lower end may afford a clue in those cases in which the head is not conclusive.

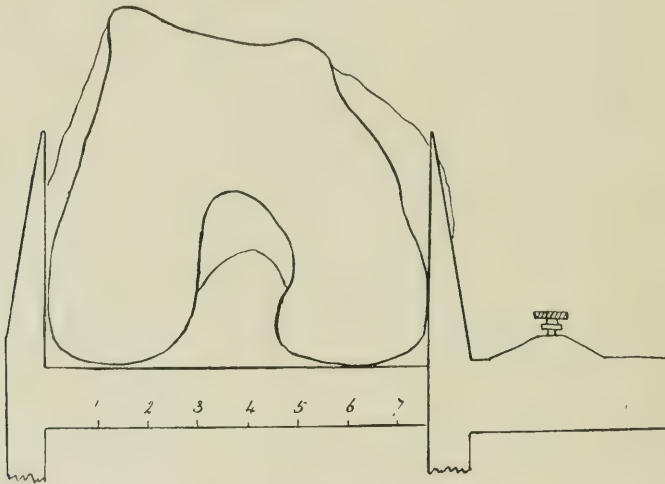


FIG. 2.

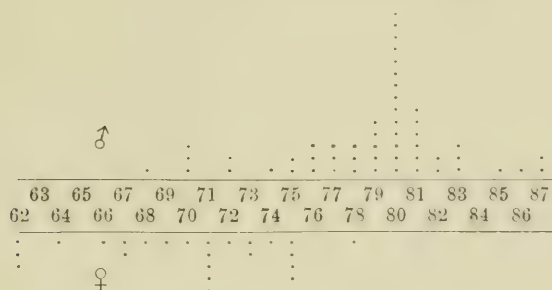
Fig. 2 shows the method of taking the width, and has been reproduced from my former paper on the Rothwell bones. The average breadth for male bones is 79 mm., and for females 69 mm. This is with the cartilage and periosteum in position, but I find that when dry bones are measured 2 mm. should be allowed for these.

From this chart it appears that any measurement between 70 and 75 mm. (inclusive), although probably female, would be very unreliable. Measurements over 75 would seem to be almost certainly male, and those under 70 equally certainly female, though the chance of these being helpful is not as great as one would like, because the bones which have indefinite heads have also very often indefinite lower ends.

To illustrate this, one may notice that there are among our records 28 cases in which the head is between 44 and 48 mm. inclusive. These,

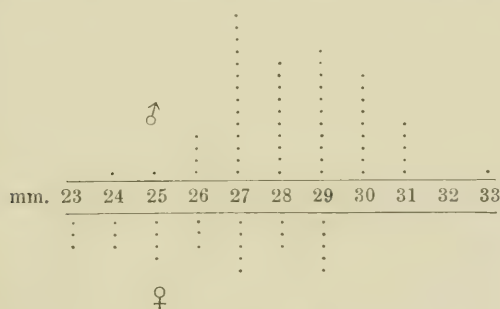
therefore, are of doubtful sex, and in only 5 of them did the lower end accurately indicate the sex. In 2 the measurement of the lower end was unobtainable, in 2 it was absolutely misleading, while in 19 it varied between 70 and 75, the indefinite region.

TABLE IV.—CHART OF LOWER END WIDTHS.



*The Least Transverse Diameter of the Shaft.*—This I think is an important measurement, because it is not only of some little use for sexing purposes, but it affords a useful clue to the robustness of the skeleton.

TABLE V.—CHART OF THE TRANSVERSE DIAMETER OF THE SHAFT IN THE TWO SEXES.



The average male measurement is 28 mm. and the female 26 mm., but it is evident that between 25 and 29 the overlap of the variation of the sexes is so great that it will only be safe to presume that anything under 25 is probably female and over 29 male.

*Platymeria.*—The amount of platymeria is not usually a point which we expect to help us in determining sex, but we are gradually accumulating information on this interesting condition, and it will be well to see whether these London bones can help us.



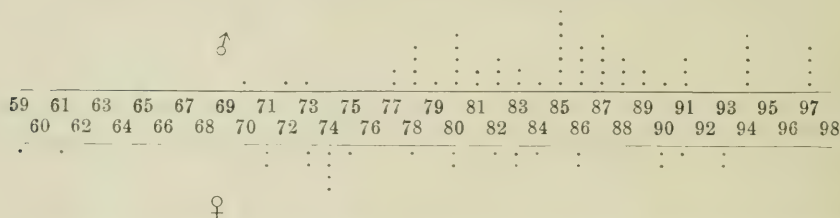
A few years ago we regarded platymeria as a characteristic of certain uncivilised or partly civilised races, and it was thought to be the result of the action of muscles used in hill climbing. Lately it has been found quite well marked among Bronze Age and Saxon dwellers in the British Isles, while still more lately I have been able to show that among the mediæval inhabitants of Rothwell over 11 per cent. of the males and 27 per cent. of the females had femurs, the platymeric index of which was below 75: and an index of 75 means that the bone is strikingly platymeric to the eye, unaided by any measurements.

I therefore came to the conclusion that at Rothwell platymeria, contrary to Manouvrier's experience, is a good deal commoner in women than in men.

In the 31 modern English males with which I am now dealing the average index is 85·5 on the right and 85 on the left, only two individuals showing an index of less than 75.

In the 13 females the average index is 80 on the right and 79 on the left, but the interesting point is that 6 out of the 13 (46 per cent.) had an index of less than 75 on one or both sides.

TABLE VI.—CHART OF THE PLATYMERIC INDICES IN THE TWO SEXES.



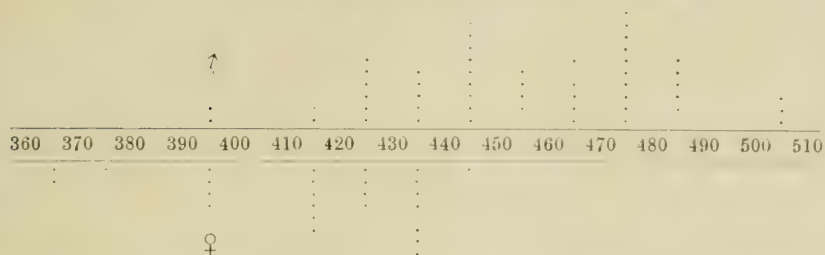
The above chart suggests that very high indices are probably male, and very low probably female. Anything between 75 and 90, however, would appear too uncertain to trust.

*The Maximal Length.*—This, of course, must not be taken too seriously as an indication of sex, nor, on the other hand, can we afford to ignore it.

There is no doubt that a short femur should suggest a female bone other things being equal, though the amount of sexual difference probably varies in different races and under different conditions of culture. Among the English middle and lower classes of to-day I believe that the difference in height between the sexes is appreciably greater than it was among the Anglo-Saxons.

From the accompanying chart it would appear that a femur length of over 450 mm. or even 440 is strongly in favour of the male sex, while one under 400 is probably female.

TABLE VII.—MAXIMAL LENGTHS IN THE TWO SEXES.



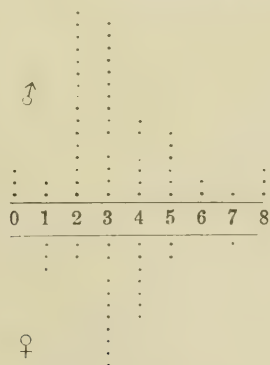
*Difference between Maximal and Oblique Lengths.*—Professor Elliot Smith found that among ancient Egyptians the most satisfactory test of the sex of the thigh-bone was the much greater difference between the maximal and oblique lengths in the female than in the male, and this he ascribed to the greater obliquity in the female.

I do not think that this applies to English people, for at Rothwell I found that the obliquity of the female bone was, on an average, only one degree more than that of the male. However, as the sexing of the Rothwell bones is partly the subject of this inquiry, I must confine my observations for the present to these London femurs, the sex of which I really do know.

In the males the average difference is 3·4 mm. on the right side, 3·2 on the left. In the females, 3·5 mm. on the right, 3·0 on the left.

As the point is evidently an important one in a negative way, the accompanying chart will show the range of variation in the differences.

TABLE VIII.—CHART OF DIFFERENCE BETWEEN MAXIMAL AND OBLIQUE LENGTHS.



*The Length-thickness Index.*—This will be a convenient place to mention another negative result. I had hoped that the ratio between the

length and least diameter of the shaft might give a clue which would be valuable in those cases in which the head-length index proved valueless. After working out all the indices, I found that the overlap of the variations in the two sexes was so enormous that the work was valueless, and I only mention it to save others from a like disappointment. It will now be as well to recapitulate the tests on which I propose to depend for sexing English femurs.

1. Femur heads with a vertical diameter of over 48 mm. are males, under 44, females. In dry bones without cartilage 1 mm. should be subtracted.

In bones between 44 and 48 mm. one or more of the following tests may be available:—

2. Length-head index . . . . . -104 ♀ +109 ♂.

3. Width of lower end . . . . . -70 mm. ♀ +75 ♂.

(2 mm. should be taken off where there is no cartilage or periosteum).

4. Least transverse width of shaft -25 mm. ♀ +29 ♂.

5. Platymetric index . . . . . -75 ♀ +90 ♂.

6. Maximal length . . . . . -400 mm. ♀ +450 ♂.

Having done this, I will deal with the 82 femurs obtained from the London bodies as if they were brought me with their labels removed and with only a reference number attached by which the sex might be looked up, and I will see how far the tests which I have just recapitulated will enable me to sex them accurately.

In the first place, 53 of the 82 (65 per cent.) have heads which are either over 48 or under 44 mm. It is the other 29, with heads between and including these numbers, with which we are particularly interested, and it may help in their consideration if they are picked out and their various crucial measurements placed beside them.

No.	A. Maxl. Length.	B. Head.	C. Head-length Index.	D. Width of Lower End.	E. Tr. Width of Shaft.	F. Platymetric Index.	No. in List.
1	433	48	111	79	29	85	3 ♂. R.
2	450	48	107	...	28	97	4 "
3	442	48	109	80	29	94	7 "
4	391	44	113	68	27	84	8 "
5	447	47	105	72	27	97	14 "
6	442	48	109	80	29	94	18 "
7	426	46	108	70	28	86	19 "
8	428	46	108	75	28	80	26 "
9	435	47	108	79	30	83	30 "
10	429	48	112	75	27	82	31 "

No.	A. Maxl. Length.	B. Head.	C. Head-length Index.	D. Width of Lower End.	E. Tr. Width of Shaft.	F. Platymetric Index.	No. in List.
11	450	48	107	...	29	82	4 ♂. L.
12	395	46	116	70	26	85	8 "
13	445	47	106	72	27	94	14 "
14	414	45	109	70	29	86	19 "
15	413	45	109	77	27	91	24 "
16	423	44	104	74	28	77	26 "
17	440	47	107	77	28	86	30 "
18	434	44	101	71	28	90	1 ♀. R.
19	396	45	114	70	26	71	2 "
20	429	47	110	78	26	80	6 "
21	426	45	106	73	26	78	7 "
22	437	46	105	71	27	80	8 "
23	420	44	105	74	25	84	9 "
24	436	44	101	71	29	93	1 ♀. L.
25	430	47	109	75	29	74	6 "
26	426	45	106	73	27	78	7 "
27	434	46	106	71	29	82	8 "
28	422	46	109	75	29	59	10 "
29	417	45	108	72	28	91	14 "

- No. 1 is a male bone by tests C and D; it has no female characteristics.
- „ 2. A, F, and B all suggest male; nothing female.
- „ 3. B, C, D, E, and F point to male; nothing female.
- „ 4. A, B, D suggest female. The only male point is the head-length index of 113. C. I fear that I should have made this female.
- „ 5. Everything indefinite except F, which points strongly to a male.
- „ 6. B, C, D, and F point to male; nothing definitely female.
- „ 7. Every characteristic is negative, but I fear that the small lower end would have inclined me to a female decision.
- „ 8. C, D, and E approach the male border-line, and there is no similar approach to the female anywhere.
- „ 9. D and E are definitely male.
- „ 10. B and C are definitely male.
- „ 11. Nothing is definite, but all measurements lean to the male side.
- „ 12. C strongly male; others indefinite, except A, which would be female were it not so strongly overpowered by C as to make one almost sure that a small man is being dealt with.
- „ 13. F definitely male, others indefinite.



No. 14. C is just on the male line, and so is E. Similarly, B and D are near the female line. Using F, therefore, as the decisive factor, it is found fairly close to the male limit, and so I think the bone should be regarded as that of a small male.

„ 15. D and F are distinctly male, while C is on the male border-line.

„ 16. B and F are distinctly female, and there are no distinctly male characteristics.

„ 17. D and F are distinctly male.

So far these bones were all really male, and of them 3 (Nos. 4, 7, 16) appear to be female by the use of my tests

The other 14 appear to be male.

No. 18. B and C are distinctly female; D is on the female and F on the male border-line.

„ 19. A, B, D, and F point to the female sex, though C is distinctly male. The balance is certainly female.

„ 20. C and D are distinctly male, and there is nothing characteristically female about the bone.

„ 21. C and E are close to the female border, and so is F. Though there is nothing definitely pointing to either sex, the trend of these three measurements should, I think, be sufficient to turn the scale to the female side.

„ 22. C and D are comparatively female, and F approaches the female limit. There are no male features.

„ 23. B, C, and E are markedly female. D alone suggests a male, but it would need strong male evidence to upset B and C.

„ 24. B is presumably female, and so is D. C is definitely female, while E is presumably and F definitely male. On the whole the balance is towards the female sex.

„ 25. B, C, D, and E suggest a male. Only F is markedly female, but I should certainly have regarded this as a male bone.

„ 26. This is a very indefinite bone, though it seems to lean to the female border on most counts.

„ 27. C and D are close to the female border. E, however, approaches the male. On balance it should be female.

„ 28. C, D, and E are all on the male border-line of the neutral zone, while F alone strongly suggests a female. In spite of this extreme platymeria I should have made the bone male.

„ 29. C, E, and F suggest a male. A suggests a female, but would not have counterbalanced the others in my opinion.

Of these 12 really female, though apparently doubtful, bones, therefore, 4 (Nos. 20, 25, 28, and 29) have been wrongly sexed and 8 rightly.

The net result of my endeavours is that, of the 82 femurs, 53 (65 per cent.) were at once settled correctly by the very large or very small size of their heads; while of the 29 which were regarded as doubtful, 22 were accurately and 7 inaccurately sexed. I have therefore made seven mistakes in 82 bones, or 8.5 per cent. failures and 91.5 per cent. successful attempts.

It was shown on p. 347 that, by merely taking the head diameters, 70 of the 82 bones could be accurately sexed, and that only six instead of my present seven mistakes were made; but then six bones were left on the border-line, with a head measurement of 46, and in order to make the two methods comparable I should be allowed to set aside the six most puzzling cases, which would no doubt have reduced my mistakes considerably. Of course I realise that no anatomist would allow himself to depend entirely on the head measurement in sexing femurs; he would use the general impression which his trained eye would provide to supplement or correct the evidence of the calipers. This experience is, however, a most uncertain asset, and must vary a good deal in different individuals. Without practical tests which might lead to misunderstandings it is almost impossible to estimate the value of any particular individual's sexing of femurs, skulls, or other bones, and so I think that a comparatively hard-and-fast method, giving a known error of some 8 or 9 per cent. and independent of the personal element, will prove an advantage, in spite of its greater laboriousness, if mathematical deductions are to be made from femurs the sex of which cannot be absolutely known.

Having chosen a series of sex tests for femurs and having gained some idea of their value, I now propose to reconsider my sexing of the femurs at Rothwell. In sexing these bones I was not entirely dependent on the head measurements, but took the general appearance into account, being guided in my final decision by a comparatively loose and ill-defined experience.

Now that I have reduced my experience to definite figures, I can see that there are some of the Rothwell bones which I should have sexed differently.

There are 10 femurs among the 185 males which I now believe to be females, and 4 among the 108 females which I now think males. At the cost of a good deal of labour I have rearranged these bones, and, after calculating the averages once more, find that there is no great change in the result printed on pp. 244-251 of my former paper in the *Journ. of Anat. and Physiol.*, vol. xlviii.

The following table shows how small an effect a transference of some 5 per cent. from one sex to the other makes in the average result:—

			Oblique Length.	Maxl. Length.	Head Diamr.	Width of Shaft.	Width of Lower Extremity.	Platymeric Index.
R. ♂	{	Before transfer . .	453	456	49	29	77	77
		After " . .	452	455	49	29	77	78
L. ♂	{	Before " . .	456	460	49	30	77	81
		After " . .	457	460	49	30	77	83
R. ♀	{	Before " . .	415	416	43	26	68	78
		After " . .	417	420	43	26	68	77
L. ♀	{	Before " . .	418	422	42	27	67	79
		After " . .	420	424	42	27	68	76

The chief change is to reduce the difference between the right and left maximal lengths of the female bones by 2 mm., and to increase the difference between the oblique lengths of the male bones on the two sides by a like amount. The platymeric indices of these are reduced below that of the males on either side. Incidentally, the curious want of harmony between the maximal and oblique lengths of the right female bones is smoothed out, and the maximal length gains the normal 3 mm. over the oblique. This, I think, is an indication that the rearrangement is a natural one.

Having resexed the Rothwell bones, and readjusted their averages, it will be interesting to compare them with the modern London bones, although the latter, as has been pointed out already, are not quite typical of the modern London inhabitant. We must remember, too, to make due allowance for the London bones being in the recent state with the cartilage and periosteum present, whereas the mediæval Rothwell bones were perfectly dry.

#### COMPARISON OF LONDON AND ROTHWELL BONES.

Length.	♂ R.		♂ L.		♀ R.		♀ L.	
	Obl.	Max.	Obl.	Max.	Obl.	Max.	Obl.	Max.
London . .	452	456	452	455	412	415	415	418
Rothwell . .	452	455	457	460	417	420	420	424

By this we see that the Rothwell bones were in almost every case longer than the modern London ones, but, as the latter were measured in the recent state, another 3 mm. must be subtracted from them for the articular cartilage and the effects of drying.

If the maximal length average is taken with this deduction from the London bones we get the following statures:—

	Male.		Female.	
	London.	Rothwell.	London.	Rothwell.
Maxl. femur length .	453 mm.	458 mm.	414 mm.	422 mm.
Stature . . . .	167·7 cm. (actual)	168 cm. (Pearson)	155 cm. (actual)	160 (Pearson)

From this it will be seen that the London males were practically the same height as those at Rothwell, though the London females were 5 cm. shorter than the Rothwell females.

When we consider that these London paupers and lunatics were the aged derelicts of the town, we have no reason to think that the passage of five centuries has brought any material decrease of stature.

*Diameter of Head.*—After deducting 1 mm. from the heads of the London femurs for the cartilage, as already determined, the following comparison with Rothwell is possible:—

	♂	♀
London . . . . .	48 mm.	42 mm.
Rothwell . . . . .	49 „	42 „

What little difference there is, is thus in favour of Rothwell.

It may be of interest to compare the maximal length-head indices in the two collections, since they have been used as sex tests:—

	♂	♀
London . . . . .	109 mm.	104 mm.
Rothwell . . . . .	107 „	101 „

Obviously Rothwell is a little lower in this index than London, and I have taken this into consideration in resexing the former bones.

*Least Transverse Diameter of Shaft.*

	♂	♀
London . . . . .	28 mm.	26 mm.
Rothwell . . . . .	30 „	27 „

This is a valuable index for estimating the robustness of the individual, and the averages show that the Rothwell people had at least better developed thighs than our modern London paupers.



*Transverse Width of Lower End.*—It has been stated already that a deduction of 2 mm. for cartilage and periosteum is necessary in comparing recent with dried bones. With this allowance the following comparison is obtained :—

	♂	♀
London . . . . .	77 mm.	68 mm.
Rothwell . . . . .	77 „	68 „

*Platymeria.*—The following is a comparison of the platymeric indices. It has been pointed out already that an index of 75 means that a bone is markedly platymeric to the eye.

	♂		♀	
	R.	L.	R.	L.
London . . . . .	85.5	85 mm.	80	79 mm.
Rothwell . . . . .	78	83 „	77	76 „

This table shows that the mediæval Rothwell bones were distinctly more platymeric than the modern London ones, and that in both cases platymeria is more pronounced in the female than in the male.

#### CONCLUSIONS.

The conclusions to which I have come must be regarded as tentative and suggestive rather than final, because I know quite well that they may be modified by a larger series, particularly of female bones. Still, experience with other bones makes me believe that the modifications will not be great enough to affect the conclusions seriously.

1. I think that I have suggested a series of sexual tests which will ensure a uniform method of sexing for English bones if other anatomists care to adopt them. No doubt they will need modification when bones of other races are dealt with.

2. The tests should give a fairly steady accuracy of some 91 or 92 per cent. against the varying accuracy of different observers the personal equation of whom is unknown.

3. The use of these measurement tests is, I think, a little more accurate than the judgment by eye of an experienced anatomist, but the difference is not very great; the chance of rightly sexing an individual bone is certainly rather greater, but the averages of a large series are only slightly if at all altered. When, however, experience is not available these tests are more reliable by some 6 per cent. than deciding the sex by the size of the head of the femur.

4. The available evidence suggests that London paupers and lunatics

are of nearly the same stature as mediæval midland Englishmen, though they are not as robustly built.

5. Platymeria, whatever its cause, is commoner in women than in men, and is less marked in London paupers of to-day than in English people of the Middle Ages.

6. Incidentally, I have determined, to the best of my ability, the deductions necessary for comparing dry bones with those in the recent state.

TWO CASES, CONSIDERED FROM THE DEVELOPMENTAL STANDPOINT, IN WHICH THE RIGHT SUBCLAVIAN ARTERY AROSE FROM THE ARCH OF THE AORTA BEYOND THE ORIGIN OF THE LEFT SUBCLAVIAN ARTERY; WITH A NOTE ON THE RELATION OF THE SUBCLAVIAN VEINS TO THE CARDINAL SYSTEM. By REGINALD J. GLADSTONE, M.D. Aberd., F.R.C.S. Eng., F.R.S.E., *Lecturer on Anatomy, University of London, King's College*; and C. P. G. WAKELEY, *Assistant Demonstrator of Anatomy, King's College, London.*

THESE cases, as is well known, are due to the persistence in the adult of the distal portion of the right dorsal aorta of the embryo and the severance of its connexion with the fourth arterial cephalic arch. The part of the

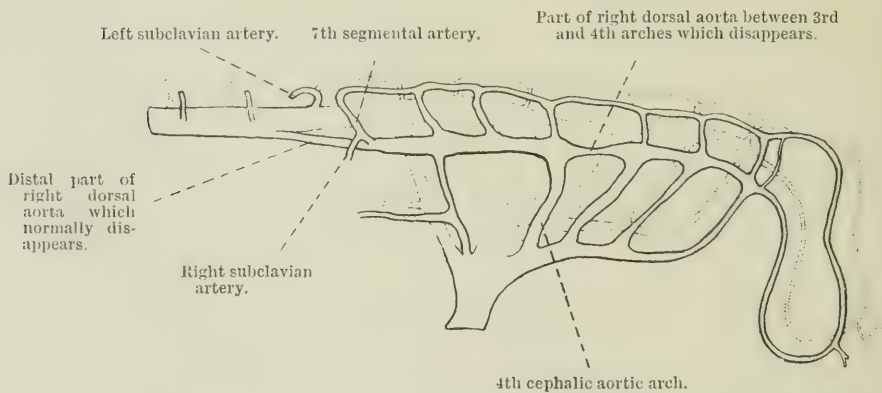


FIG. 1.—Diagram of the cephalic portion of the arterial system. Modified from Cunningham's *Text-book of Anatomy*.

right dorsal aorta which persists is obviously that which lies between the junction of the right with the left dorsal aorta and the origin of the right 7th dorsal segmental artery (fig. 1). The 4th right cephalic aortic arch and that part of the right dorsal aorta between the origin of the 3rd and 7th somatic segmental arteries disappears, except in those cases

in which the right vertebral artery is given off from the innominate artery.

There is some uncertainty, however, as to whether any part or the whole of the distal portion of the right dorsal aorta is normally represented in the adult by anastomosing vessels joining the subclavian artery with the aorta. It is with the object of clearing up this difficulty that we have turned our attention to the condition of the right dorsal aorta and intercostal arteries in the later stages of embryonic development, and the normal anastomosis of arteries in the adult which takes place across the anterior aspect of the upper thoracic vertebræ and ribs.

CASE 1.<sup>1</sup>—The subject in which this abnormality occurred was a male aged 71 years. The right subclavian artery (fig. 2) commenced at the level of the 4th thoracic vertebra from the posterior aspect of the arch of the aorta. It pursued an upward course from left to right behind the trachea and œsophagus to the outer border of the 1st rib. It measured 4 inches in length, and gave off the following branches:—

1st part:—

1. Vertebral.
2. Costo-cervical trunk.
3. Inferior thyreoid.
4. A common trunk dividing into transverse scapular, transverse cervical, and internal mammary.

2nd part:—

None.

3rd part:—

5. Posterior scapular (B.N.A., descending branch of transverse cervical artery).

1. The vertebral artery arose from the upper and posterior aspect of the subclavian, and entered the foramen in the transverse process of the 6th cervical vertebra.

2. The right costo-cervical artery divided into:—

- (a) The superior intercostal artery. This vessel supplied the 1st intercostal space, and anastomosed with the 1st right aortic intercostal which supplied the 2nd intercostal space, and with a small branch from the internal mammary.
- (β) The deep cervical artery which passed upwards and backwards below instead of above the neck of the 1st rib.

3. The inferior thyreoid artery. This was a large branch which sprang

<sup>1</sup> Dissected by C. P. G. Wakeley.



from the upper border of the main artery. It passed in front of the vertebral artery behind the carotid sheath, and in front of the sympathetic cord.

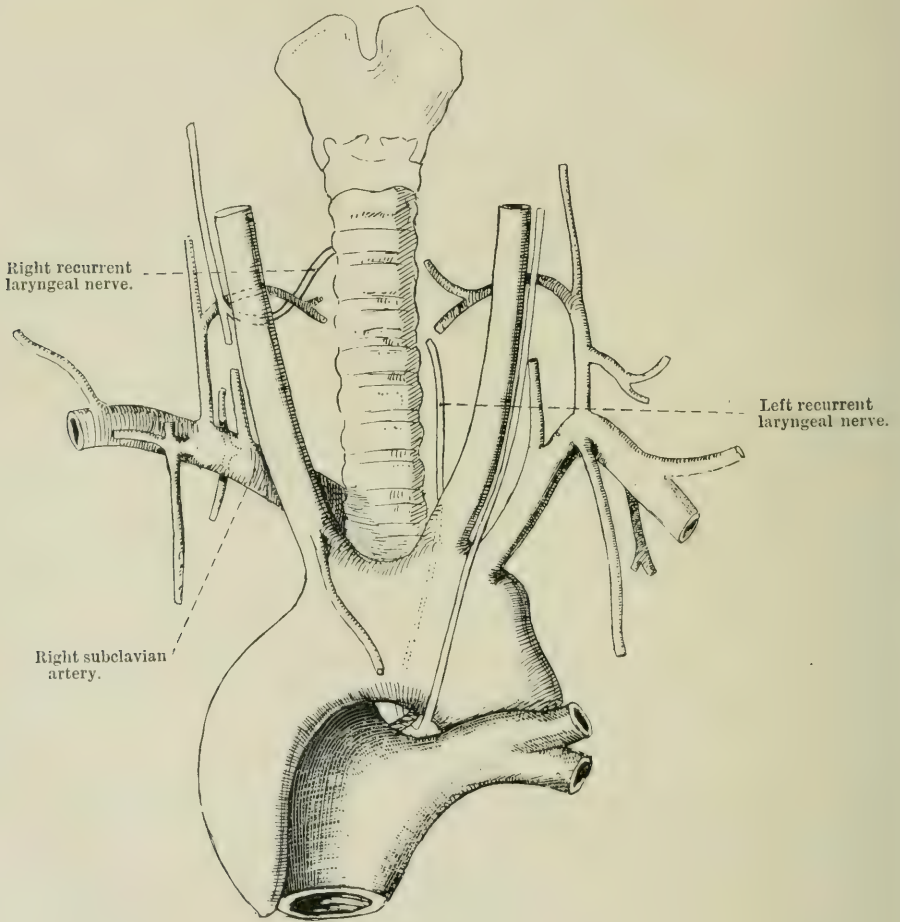


FIG. 2.

4. The common trunk mentioned above was a large branch springing from the anterior aspect of the first part of the subclavian artery. It gave off a lateral trunk which immediately broke up into two branches, the transverse cervical and the transverse scapular. The main artery was continued as the internal mammary.

5. The posterior scapular arose from the upper surface of the subclavian

lateral to the anterior scalene muscle. No "arteria aberrans" was given off from the subclavian artery.

The right common carotid artery arose from the arch of the aorta in front of the trachea and opposite the body of the 3rd thoracic vertebra. It gave off close to its origin a small branch which supplied the thymus gland. The left common carotid and left subclavian arteries arose, close together, from the summit of the aortic arch. The branches given off from the left subclavian were:—

- |                      |                         |
|----------------------|-------------------------|
| 1. Vertebral.        | 4. Highest intercostal. |
| 2. Internal mammary. | 5. Posterior scapular.  |
| 3. Thyroid axis.     |                         |

The right inferior laryngeal nerve arose from the vagus at the level of the transverse process of the 6th cervical vertebra, it passed downwards, then turned round the inferior thyroid artery, and finally pursued its usual course upwards between the œsophagus and trachea to the larynx. Where it was crossed by the inferior thyroid artery it was held down by a slip of fascia. The left recurrent laryngeal nerve was normal with regard to its relations to the ligamentum arteriosum and arch of the aorta.

The thoracic duct on reaching the body of the 4th thoracic vertebra turned to the right along the lower border of the right subclavian artery, its course here being probably determined by the position of the abnormal artery. The duct near its termination split into two parts which opened separately into the junction of the right internal jugular and subclavian veins. On the left side a fair-sized lymphatic vessel passed upward on the vertebral column through the superior mediastinum, and joined a tributary from the left upper extremity to form a common trunk, which opened into the terminal part of the left internal jugular vein.

CASE II. (fig. 3).<sup>1</sup>—In this specimen, from a female subject aged 63, the right subclavian artery sprang from the posterior aspect of the arch of the aorta, about half an inch beyond the origin of the left subclavian: it then passed upward and to the right, behind the left inferior laryngeal nerve, œsophagus, trachea, and right vagus nerve to the interval between the anterior and middle scalene muscles. It gave off the following branches:—

- |                          |                           |
|--------------------------|---------------------------|
| 1. Vertebral.            | 3. Thyreo-cervical trunk. |
| 2. Costo-cervical trunk. | 4. Internal mammary.      |

There was no "vas aberrans."

The 1st right aortic intercostal artery supplied the 3rd and 4th intercostal spaces and sent a small branch upward to anastomose with the highest intercostal artery.

<sup>1</sup> Dissected by Mr H. B. Eisenberg and Mr G. K. Burge.

The left subclavian artery gave off:—

- |                         |                         |
|-------------------------|-------------------------|
| 1. Vertebral.           | 4. Inferior thyreoid.   |
| 2. Highest intercostal. | 5. Transverse cervical. |
| 3. Internal mammary.    | 6. Transverse scapular. |

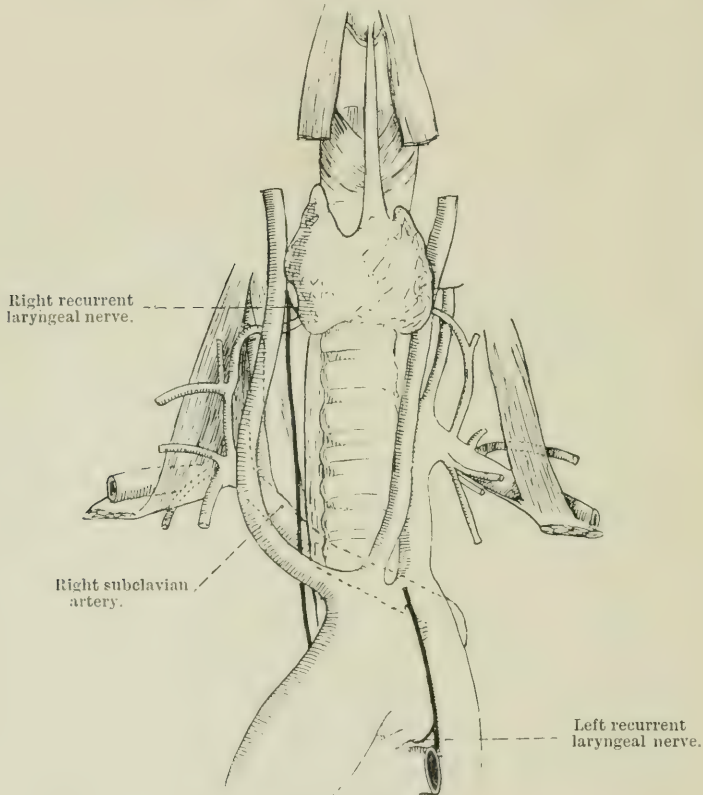


FIG. 3.

The right and left common carotid arteries arose from a short common trunk near the summit of the arch. The right inferior laryngeal nerve was given off opposite the 6th cervical vertebra, and after passing downward for a short distance turned round the inferior thyreoid artery and then passed upward to the larynx, between the œsophagus and trachea, as in Case I. The left inferior laryngeal nerve pursued its usual course. The thoracic duct had the normal course and relations, and terminated as usual at the junction of the internal jugular with the subclavian veins.

In an article by E. Pearce Gould (6), he expressed the view that in

those "cases in which the right subclavian artery arises directly from the arch of the aorta as its leftmost branch, that the abnormal vessel, which is a persistent part of the right dorsal aorta of the embryo, is most probably represented in the normal adult by an anastomosis between the 'vas aberrans' coming from the aorta, and a second aberrant artery given off from the subclavian. The latter is described in some text-books as forming a fairly constant accessory branch of the normal subclavian artery, which arises from this vessel close to its origin, and medial to the vertebral artery." This view differs from the theory previously held, namely, that the abnormal subclavian artery represents a persistent part of the right dorsal aorta of the embryo, *and that this is normally represented in the adult by an anastomosis of a branch of the highest intercostal artery of the right side with the aberrant artery from the aorta or 1st right aortic intercostal artery.* The objections to the latter part of this statement are (1) that according to this view the common longitudinal trunk of the right and left highest intercostal arteries would not be homologous, for the true homologue of the trunk of a right highest intercostal artery would, upon the left side, obviously be a part of the aortic arch, the commencement of the descending thoracic aorta; and (2) according to this theory the point of origin of the right highest intercostal artery in the normal condition ought to be medial to the vertebral artery and other branches of the subclavian artery (see fig. 5).

In a specimen of double aortic arch described by Professor Curnow, and preserved in the Anatomical Museum of King's College, the right arch, which is considerably larger than the left, gives off two branches, namely, the right common carotid and right subclavian; the latter gives off the right vertebral artery, thyreoid axis, internal mammary, and an artery which crosses the neck of the 1st rib and supplies the 1st and 2nd intercostal spaces. This appears to be the highest intercostal artery given off directly from the subclavian. It arises distal to the origin of the vertebral artery, and undoubtedly anastomosed with the 1st right aortic intercostal artery, which supplies the 3rd space. The left superior intercostal artery is also present, and evidently anastomosed with the 1st left aortic intercostal artery.

This specimen obviously supports the view expressed by Mr. E. Gould, namely, that the normal anastomosis of the highest intercostal artery of the right side with the 1st right aortic intercostal artery does not represent the terminal part of the right dorsal aorta of the embryo, for in the same subject there coexists a persistent distal part of the right dorsal aorta and an anastomosis between the highest intercostal artery of the right side with the 1st right intercostal artery, and a similar anastomosis is also



present on the left side, along with the persistent distal part of the left dorsal aorta. Whether the distal part of the right dorsal aorta is represented in the normal adult subject by an anastomosis of the aberrant branch of the aorta with an aberrant branch of the right subclavian is also doubtful.

In sixteen adult dissecting-room subjects in which we have specially looked for the aberrant branch of the right subclavian artery we could find no trace of it, and we therefore conclude that it is certainly not normally present in the adult.

Moreover, on examining a series of human embryos above 17 mm. in length, the distal part of the right dorsal aorta seems to have disappeared as completely as that part which lies between the 3rd and 4th arterial arches.

In a 10-mm. human embryo the distal part of the right dorsal aorta is considerably less than half the diameter of the left (fig. 4). The two vessels join to form the common dorsal aorta at the level of the 1st thoracic nerves. The common stem which divides into the right vertebral and subclavian arteries springs from the dorsal aorta as a segmental branch, which arises at the level of the 8th cervical nerves. The right dorsal aorta gives off one segmental artery of small size, below the origin of the subclavian artery. The next segmental artery (1st right aortic intercostal artery) arises below the point of union of the two dorsal aortae.

In a 17-mm. human embryo belonging to Professor Waterston, which was obtained at an operation for tubal pregnancy, and which is exceptionally well preserved, the distal portion of the right dorsal aorta has almost disappeared. We have, however, been able to trace it (see fig. 5) from the common stem which divides into right vertebral and subclavian arteries down to its junction with the left dorsal aorta. This junction occurs just below the level of the bifurcation of the trachea.

About the middle of its course between these two points the lumen of the artery is obliterated, and the vessel can only be recognised by the concentric arrangement of the nuclei of its muscular wall. The lumen of the artery is occupied by an unstained hyaline substance which in some of the sections contains degenerated blood corpuscles. At the cephalic and distal ends of the artery, however, the vessel is more easily identified, and its lumen contains nucleated blood-cells continuous with those in the right subclavian artery and the aorta. Below the point of union of the right and left dorsal aortae the 1st aortic intercostal arteries are given off close together, and course laterally and upward behind the trunks of the sympathetic nerves. Each artery anastomoses, as in the adult, with a descending branch which appears to be the highest intercostal artery of

the corresponding side. The anastomosing vessel thus formed lies behind and lateral to the sympathetic trunk, whereas the aortic arch, the distal part of left dorsal aorta, and the degenerating distal part of the right

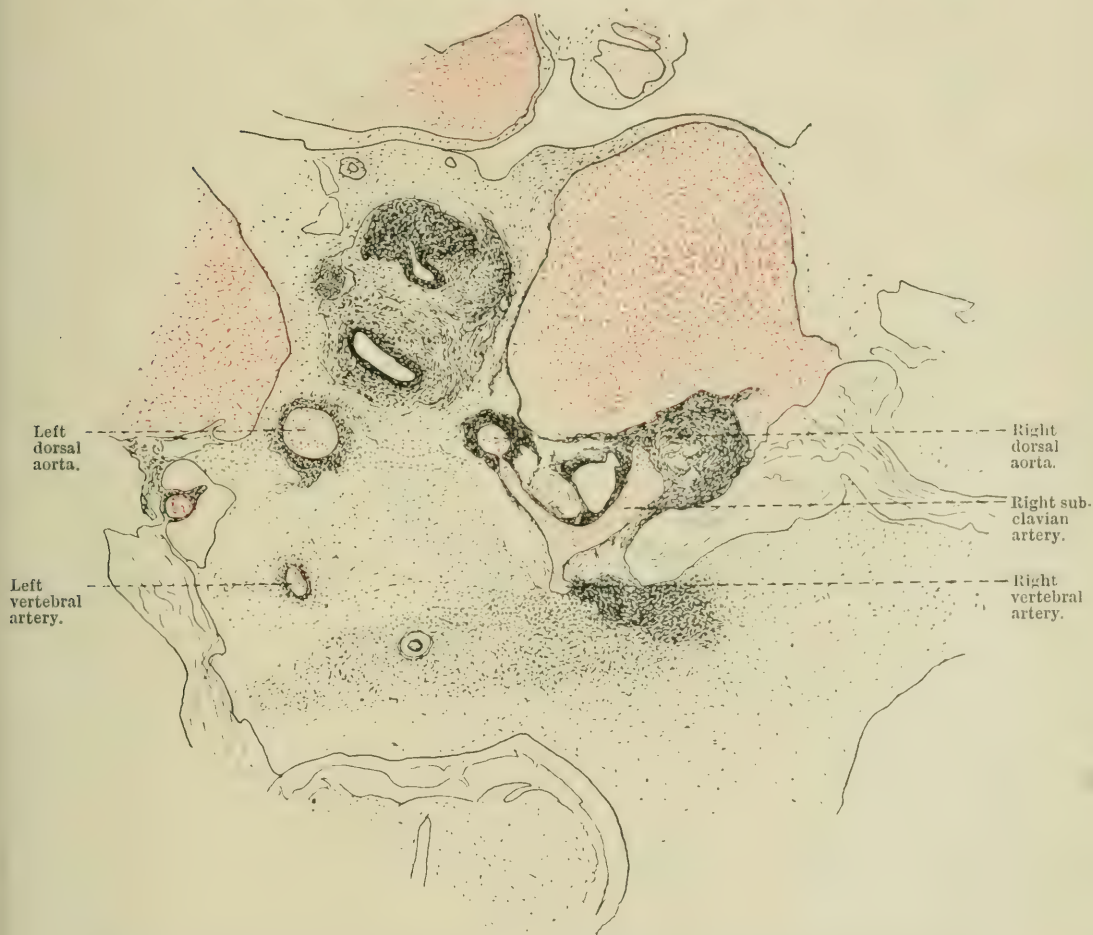


FIG. 4.—Transverse section through a 10-mm. human embryo showing the commencing atrophy of the right dorsal aorta and origins of the right subclavian and right vertebral arteries.

dorsal aorta lie ventral and mesial to the sympathetic trunk. It is obvious, therefore, that this anastomosis of the adult cannot represent the distal part of the right dorsal aorta, for in a 17-mm. embryo both the anastomosis and the right dorsal aorta coexist, and are seen side by side in the same sections. Further, if the first stage of the abnormal right subclavian artery

represented an enlargement of this anastomosis, the abnormal subelavian artery ought to pass dorsal to the sympathetic trunk instead of ventral to it.

Fig. 5, which is drawn from a linear reconstruction of the main vessels of this region, shows that the right subelavian artery consists of two parts, (1) a proximal portion of large size which courses vertically downwards from the bifurcation of the innominate artery to the origin of the common trunk which divides into the vertebral and the distal part of the right subelavian artery, and (2) a horizontal part which courses laterally into the limb bud.

The right vertebral artery is of large size. The left vertebral (not shown in the drawing) is much smaller. It is given off from the posterior aspect of the left dorsal aorta (aortic arch) about midway between the origins of the left subelavian and left common carotid arteries.

It will be observed that the left subelavian artery at this stage of development still arises below the junction of the "ductus arteriosus" with the left dorsal aorta, and is quite separate from the left vertebral artery, which as mentioned above, springs in this specimen as an independent branch from the posterior aspect of the left dorsal aorta.

The drawing also shows the position of the right and left inferior laryngeal nerves. The former passes backwards in the angle which is formed between the innominate artery and the first part of the right subelavian artery, and the latter round the termination of the "ductus arteriosus."

The "ansa subelavia" (a. Vieussensii) on the right side surrounds the common trunk which divides into the vertebral and the distal part of the right subelavian artery.

Both subelavian arteries arise at a relatively low level when compared with the position which they occupy in the adult. Moreover, the vessels springing from the arch of the aorta (innominate, left common carotid, and left subelavian) are separated by considerable intervals. At a later stage, when the heart has sunk down into the thoracic cavity and the lungs have grown upward on each side of these vessels, they come to lie close together at the summit of the arch.

In embryos of 20 mm. length and over the distal part of the right dorsal aorta has entirely disappeared, the right subelavian artery has become straightened out, and both this vessel and the left subelavian artery appear to have travelled upward with regard to their relation to the aortic arch. The left subelavian artery has apparently migrated in a direction towards the head along the dorsal aorta: its origin thus comes to be cephalad to the junction of the "ductus arteriosus" with the dorsal aorta and near the summit of the arch. This change in position is obviously

due to the sinking of the heart and its main vessels from the upper into the middle region of the thoracic cavity. The distal parts of the sub-

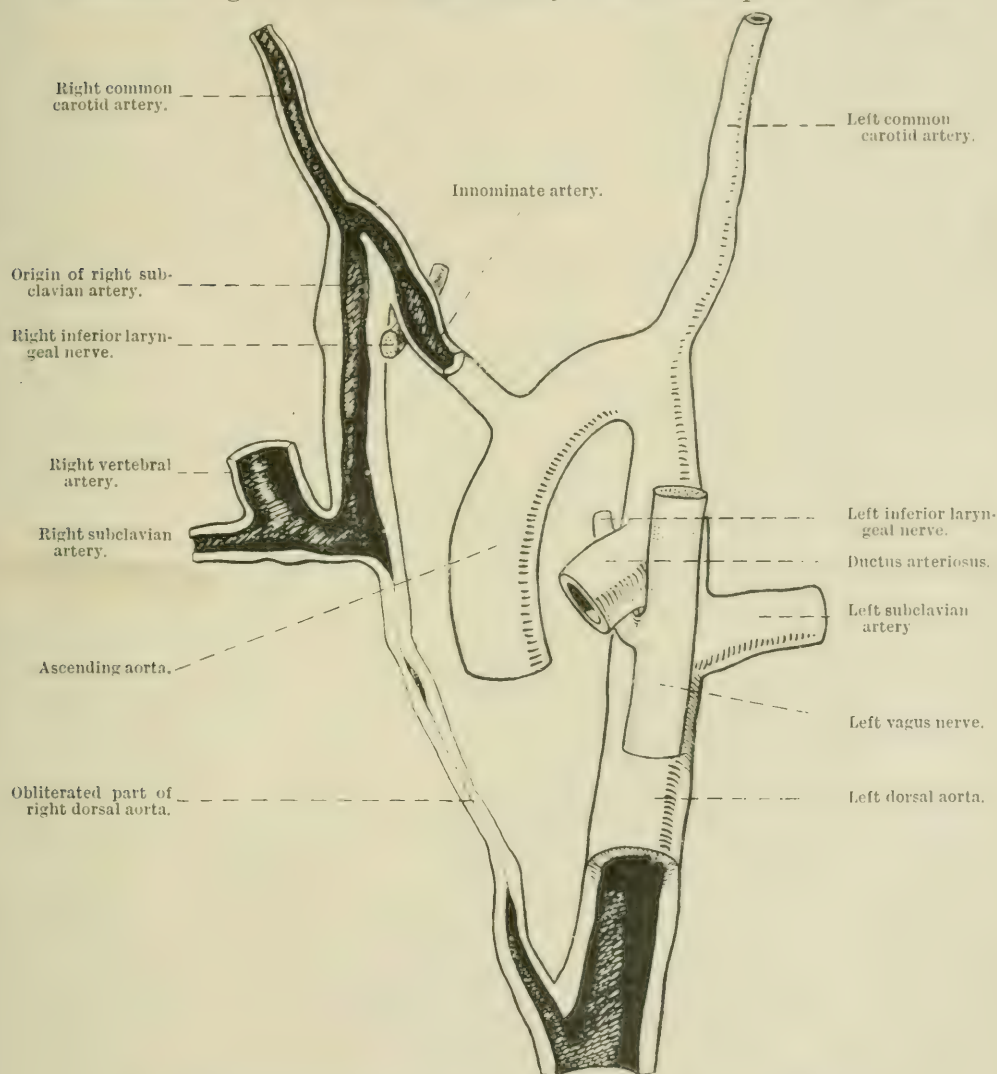


FIG. 5.—Linear reconstruction of the main blood-vessels of a 17-mm. human embryo, showing the obliteration of the distal part of the right dorsal aorta (mag.  $7^{\frac{1}{2}}$ ).

clavian arteries, which pass out over the 1st ribs into the arms, do not participate in this movement. The origin of the right subclavian artery from the innominate artery is, however, brought down to below the level



of the 1st rib, and thus instead of pursuing a downward course it has to pass upward, in order to reach the 1st rib. The origin of the left subclavian artery, on the other hand, is displaced upward towards the summit of the arch.

It may be worth while here to draw attention to the remarkable manner in which the origin of certain arteries, when once these vessels are definitely formed, travel along the main trunks from which they spring. Thus the subclavian arteries are represented in a reconstruction of the arterial system of a 3·4-mm. human embryo as arising from the 7th dorsal segmental arteries caudad to the origin of the primitive coeliac arteries. In a reconstruction by Ingalls of a somewhat later human embryo (4·9 mm. long), the subclavian arteries arise cephalad but quite close to the coeliac artery. It will be observed also that they lie opposite the constriction in the alimentary canal, between the dorsal pancreas and the caudal end of the stomach. The coeliac artery when once established as a single vessel (see reconstruction of a human embryo of 5-mm. length, Broman) migrates in a caudad direction to its permanent position opposite the upper border of the 1st lumbar vertebra. The position of the subclavian arteries relative to the vertebral column and the first ribs, however, remains much more fixed, and it is this fixity in their position which causes the changes to take place in their relation to the larger blood-vessels which are drawn into the thoracic cavity along with the caudad movement of the heart.

A table showing the position at different stages of development of the three main ventral branches of the abdominal aorta, viz. the a. coeliaca, a. mesenterica sup., and a. mesenterica inf., is published in Keibel and Mall's *Manual of Human Embryology*. The table is followed by a discussion of the various theories which have been put forward in order to explain the method by which this "migration" is accomplished, and the author of the article, Dr Herbert Evans, sums up the evidence in the following words: "It seems to me most probable, however, that the identity of the three main vessels is established permanently very early, and that the great shifting is due to an entirely different phenomenon—namely, to the unequal growth of the dorsal and ventral walls of the aorta." The importance of recognising this means by which the relative position of different arteries or veins arising from the same trunk vessels become changed will be appreciated by a consideration of the changes which, during development, take place in the relative position of the subclavian and the cardinal veins.

The subclavian veins when first formed by the enlargement of the primitive ulnar veins enter the posterior cardinal veins caudad to the heart

and the common cardinal veins or ducts of Cuvier. As development proceeds they appear to travel cephalad, so as eventually to open into the anterior cardinal veins (figs. 6 and 7). The explanation of this change in position appears to be due to an unequal growth in the dorso-lateral and ventral walls of the upper part of the posterior cardinal vein. This is associated with a migration in a caudad direction of the common cardinal veins, which are drawn with the heart from the cervical region into the thorax. The junction of the common cardinal veins with the anterior and posterior cardinals becomes enlarged so as to form a triangular sinus, which

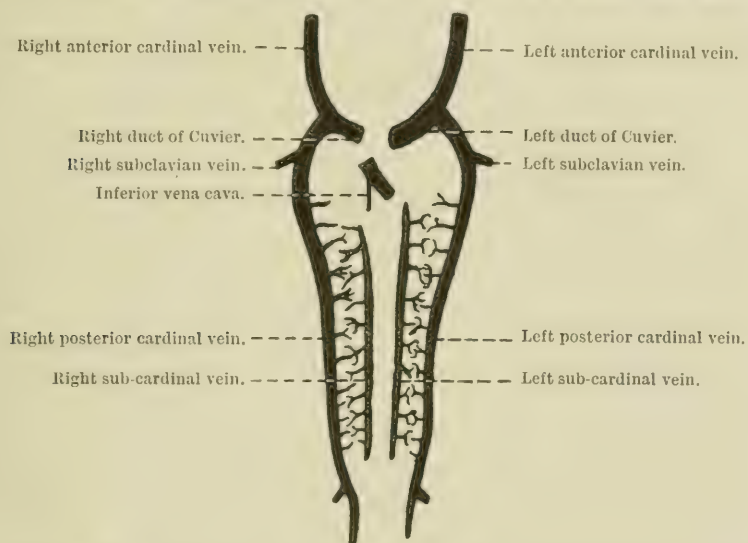


FIG. 6.—Early stage in the development of the veins, after Hochstetter, showing the entrance of the subclavian veins into the posterior cardinal vein.

receives the primitive ulnar vein (subclavian) on its postero-lateral aspect. This vein when first formed occupies a position opposite the interval between the 4th and 5th cervical nerves, but subsequently, when the embryo has reached a length of 10 mm. in its greatest diameter, it is found opposite the 8th cervical nerves, a position which it retains in the adult. The subclavian veins thus instead of migrating towards the head are at first drawn downwards in the opposite direction, and afterwards remain stationary, being fixed when these are developed by the 1st ribs, which prevent any further displacement downwards into the thorax.

The permanent innominate vein of the right side, and that part of the superior vena cava which lies above the entry of the vena azygos, will thus be formed, as far as their lateral wall is concerned, from the expanded upper

end of the posterior cardinal vein, viz. that part which lies below or caudad to the entrance of the subclavian vein. Similarly, on the left side the commencement of the left innominate vein, and the termination of the left superior intercostal vein, will be derived from the posterior cardinal vein and not the anterior cardinal, as is usually supposed.

To return from this digression to the immediate subject of our paper, we find that in the older embryos the anastomosis of the right and left highest intercostal arteries with the 1st aortic intercostal arteries may be

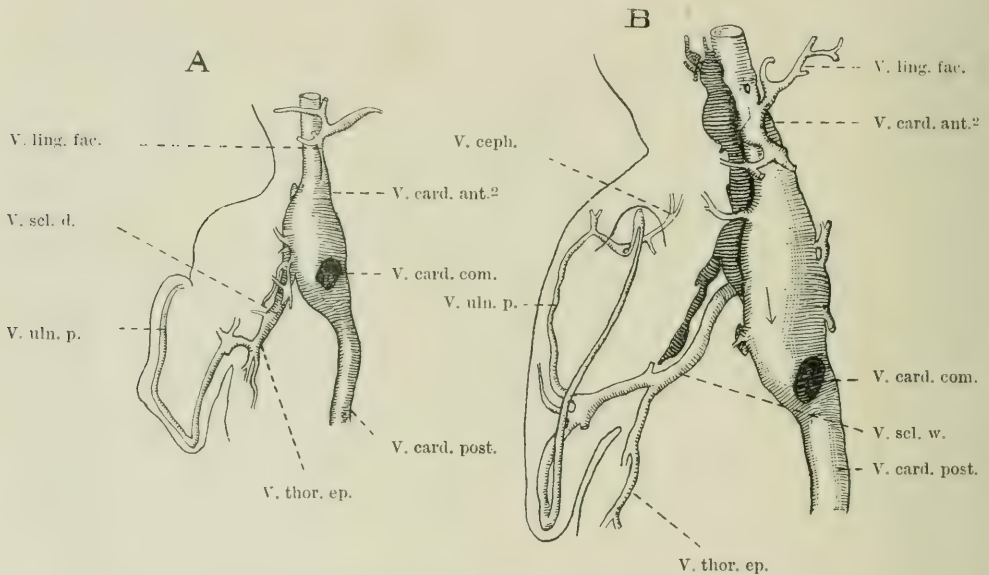


FIG. 7.—Reconstruction of the veins of the right arm in human embryo A, 11.5 mm., B, 16 mm. long. After F. T. Lewis.

quite easily traced. Moreover, the costo-cervical trunks, which give off the highest intercostal arteries, originate from the subclavian arteries, as in the adult, lateral to the origin of the vertebral arteries.

Now, if the anastomosis of the aberrant branch of the highest intercostal artery with an aberrant branch of the aorta or 1st right aortic intercostal artery represented the persistent right dorsal aorta, we should expect the costo-cervical trunk from which the intercostal branch arises to lie medial to the origin of the vertebral artery (fig. 5). Too much stress must not be put on this point, however, for the costo-cervical trunk or its highest intercostal branch is sometimes found to arise medial to the vertebral artery in the adult, as was pointed out by Professor Geddes in

an article published in the *Journ. of Anat. and Physiol.*, vol. xlv. p. 197. This relation might be explained on the assumption that as the proximal part of the subclavian artery is drawn downwards the origin of the terminal or distal part of the right dorsal aorta might be displaced to the lateral side of the vertebral artery.

The coexistence of the two vessels, viz. the abnormal right subclavian artery, and intercostal anastomosis in the same subject, in Professor Geddes's specimen, our own, and other cases previously alluded to, and also the development of the intercostal anastomosis in the 17-mm. human embryo, before the distal part of the right dorsal aorta has become completely obliterated, appears to us conclusive evidence that the abnormal origin of the right subclavian artery is usually due to the persistence of the distal part of the right dorsal aorta, and is not due to an enlargement of anastomosing aberrant arteries of the intercostal vessels.

In conclusion, we should like to express our thanks to Professor Waterston for the use of his valuable embryological material, and to Mr Walpole Champneys for the skilful manner in which he has executed the drawings.

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SOME RARE MUSCULAR ANOMALIES. By MARGARET O. MEEK,  
*Girton College.*

IN a male subject dissected in Michaelmas Term 1913 a rare form of misplacement of the insertion of the latissimus dorsi and teres major muscles was found. The terminal ends of these muscles, united and not separated by the usually existing bursa, passed upwards and, becoming attached in

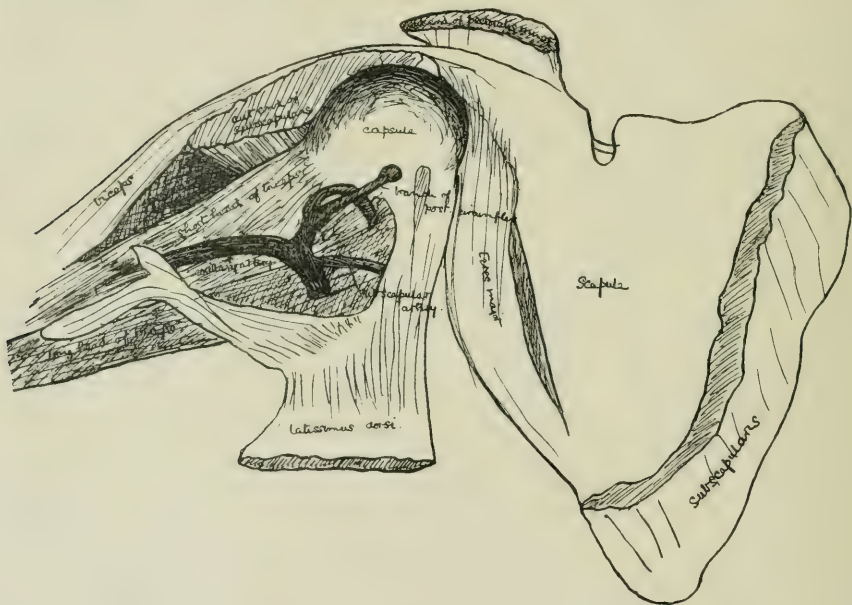


FIG. 1.

passing to the long head of the triceps, were finally inserted into the capsule of the shoulder below the coracoid process above the subscapularis insertion. The capsule was closed and did not show the usual perforation under the subscapular tendon (fig. 1). This anomalous insertion differed from any of the usual forms of the arcus muscularis axillaris in that it lay behind the axillary artery. The anomaly was present on both sides.

The same arm had a separate accessory extensor longus pollicis whose tendon lay in the same compartment of the dorsal carpal ligament as the

extensor digitorum communis, beside but separate both in belly and tendon from the extensor indicis. The first lumbrical was dicephalic, having an additional origin from the tendon of the extensor sublimis digitorum. On the ulnar side of the flexor profundus tendons for the middle and ring fingers there were separate lumbrical slips attached to the medial sides of the third phalanges, and the normally arising lumbrical for the little finger was inserted into the medial side of the ring finger.

*Tensor Plicæ Douglasii*.—In a female subject dissected during the present term there were on each side two small flat oblique muscular fasciculi under the fascia transversalis, attached laterally to the deep surface of the transversalis tendon, and medially inserted, one into the lateral margin of Douglas's fold, the other into the transversalis tendon 1 cm. above and

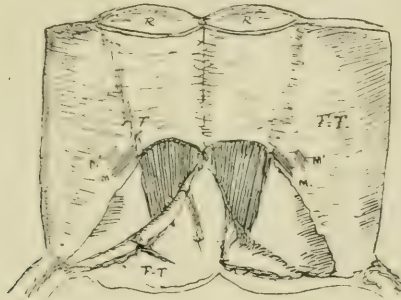


FIG. 2.

lateral to the fold. These are apparently varieties of the slip described by Professor Gruber (*Virchow's Archiv*, lxxx. p. 87) under the name "tensor laminae posterioris vaginae muscoli recti abdominis." The upper one was about 20 mm. long; the lower larger, about 35 mm. long; the interval between the two was about 10 mm., and they lay nearly parallel, ascending at an angle of about  $35^{\circ}$ ; each was about 15 mm. wide. Gruber's specimen was single on both sides, and was 10 cm. long. He gives references to three other examples of somewhat similar muscles. Other muscular slips in this locality have been described under the name pubio-peritonealis, but the present specimen is peculiar in its shortness, it having no pubic attachment, and in being double on both sides (fig. 2). The curious specimen figured by Gruber (*Bulletin de l'Académie Imp. de St. Petersbourg*, 1873) was single at origin but divided above into five bands. From his description it must have been a muscle of the same order as that now described.

ON THE SKELETON OF AN ECTROMELIC GOAT. By J. A. PIRES  
DE LIMA, *Professor of Topographical Anatomy in the Faculty of  
Medicine of Oporto (Portugal).*

IN the Catalogue of specimens of abnormal anatomy at the Museum of the Medical School at Oporto, published in 1865, is registered a "skeleton of domestic goat without the left posterior extremity." The specimen was

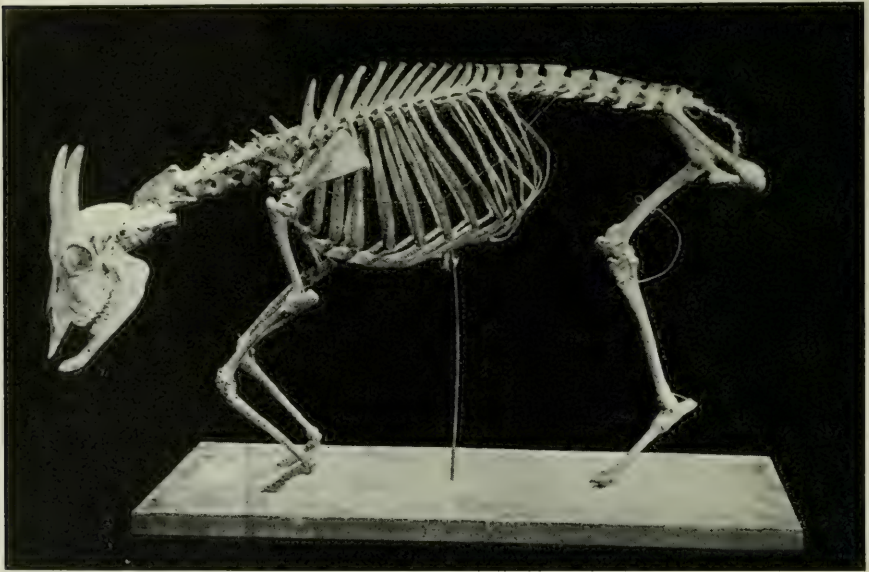


FIG. 1.—Skeleton of ectromelic goat seen from the left side.

prepared by Professor Costa Leite, and the skeleton belongs to a full-grown goat, as can be seen by the following dimensions:—The length of the vertebral column, from the external occipital protuberance to the extremity of the skeleton of the tail, is 860 millimetres. The greatest circumference of the thorax, taken at the sixth ribs, 515 millimetres.

Both these measurements were taken along the base of the spinous processes.

The skeleton (fig. 1) is in a fairly good state of preservation; it is mounted on iron rods and metal wire, and it still possesses some natural



ligaments. Of its left posterior extremity, the last three segments are totally absent, it being reduced to a very much deformed innominate bone, as we shall see on comparing it with the one on the other side, or with one of a normal goat.

*Ilium.*—The superior-external surface (fig. 2) presents the external iliac fossa slightly excavated. Normally this surface is divided into two portions by a longitudinal crest, homologous with the spine of the shoulder blade, according to Chauveau and Arloing (1). This crest ends generally in a tuberosity which is to be found in the crista iliaca (fig. 3, 1). In this skeleton, the vertex of the tuberosity (fig. 2, 1) is on the superior-external surface of the bone, at 15 millimetres distant from the crista iliaca and 1 centimetre from the external border. This is the greatest breadth of

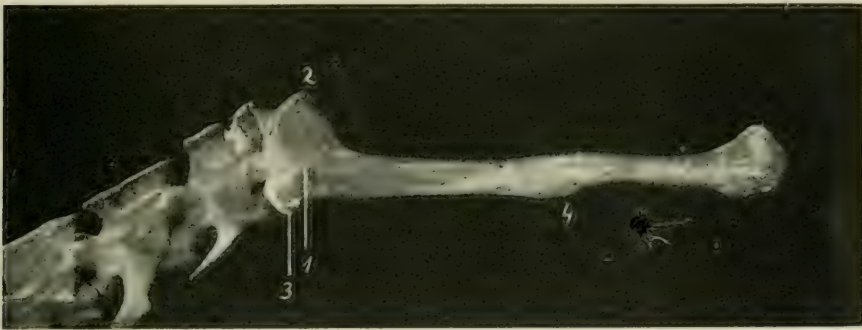


FIG. 2.—The left os coxae of ectromelic goat (superior-external surface).

the external zone of that surface of the ilium, whereas on the right side this dimension is doubled, as is the case in the bones of a normal goat. The distance between the internal angle (fig. 2, 2) and the external angle (fig. 2, 3) of the left ilium is 5 centimetres, whereas on the right side that distance is 55 millimetres: consequently, the ala of the abnormal ilium is narrower. In a normal goat the base of the ilium was also 5.5 centimetres. Both the superior-external and inferior-internal surfaces become very narrow at the posterior part.

In the goat, the crista iliaca is generally formed by a sharp border (fig. 3, 1-2), concave backwards, between the internal angle and the tubercle where the crest on the superior-external surface ends. From there onwards (1-3), the crista iliaca becomes very thick, rough, and sinuous. In the abnormal ilium the tuberosity of the external surface ends before the iliac crest (fig. 2, 1), which is rough and concave backwards along its entire length, getting gradually thicker from the internal angle



to the external one. To the latter (fig. 2, 3) there corresponds a large tuberosity, which does not exist on the other side, nor in two os coxæ of a normal goat.

The inferior-external border is blunt in front and ends up behind by a sharp crest, the most prominent point of which is 9 centimetres from the angle of the hip (fig. 2, 4). In the three other innominate bones which I have before me, next to the posterior ending of this border, before the cotyloid supracilium, there exists a large triangular depression with its base looking backwards (fig. 3, 5), which probably served for the insertion of the anterior portion of the rectus femoris, corresponding, I believe, to the impression above the upper part of the rim of the acetabulum, for the

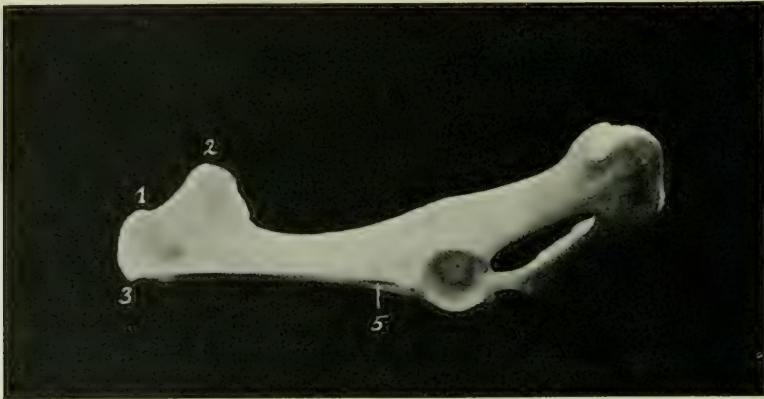


FIG. 3.—The left os coxæ of a normal goat (superior-external surface).

insertion of the rectus femoris in the human innominate bone. In both os coxæ of the normal goat I see the foramen for the nutritive vessels in this depression.

The incisura ischiadica major is blunt and nearly rectilinear. The posterior angle of the ilium, which cannot be called cotyloid, as there are no traces of an acetabulum, is very narrow and continues without the slightest demarcation into the ischium. The point of junction of the two bones probably corresponds to the most prominent part of the crest which I described in the posterior part of the inferior-external border (fig. 2, 4). The circumference of the bone, taken at its posterior angle, is merely 3.5 centimetres, whereas on the other side and in normal bones it is about 6.5 centimetres. At the thinnest point (neck of ilium), the perimeter is 28 millimetres, whereas on the right side and in the bones of a normal goat the circumference of the neck of the ilium is about 4 centimetres.

The relation between the greatest width and length of the os ilium, measured at the bottom of the acetabulum, constitutes, according to Chauveau and Arloing (1), a distinctive character of the innominate bones of goats and sheep. For the former, the index would be 0.47–0.58, whereas for the sheep it would be 0.62–0.76. The relation taken on the right os coxæ which I am studying is 0.50 ( $\frac{5}{10}$ ); on the left, taking as the posterior limit of the ilium the prominence of its infero-internal border (fig. 2, 4), the index would be 0.55 ( $\frac{5}{9}$ ), whereas in the two bones of the normal goat it is 0.45 ( $\frac{5}{11}$ ).

*Pubis*.—It is completely missing on the left side, where there are not even vestiges either of the acetabular and symphyseal branches, or of acetabulum, or of the pubic part of the foramen obturatum.

The one on the right side has the superior surface turned inwards and the inferior outwards, owing to the absence of the other pubis. It has the anterior border very short and concave, the posterior is normal, and the internal is nearly flat, being mistaken almost for the superior surface, which is deviated, as I have said.

*Ischium*.—The superior surface is narrow, very concave, and turned inwards. It measures but 2.5 centimetres in width, whereas the width of the right bone is 3.5, and of normal bones 4 centimetres. The inferior surface, contrary to what happens usually, is very convex and turned outwards.

The anterior border is more or less normal, and forms a notch (fig. 4, 1), the concavity of which is turned forwards and upwards, and represents the posterior or ischiatic part of the foramen obturatum, the only one that exists. The posterior border, very thick at its postero-external part, is curved, with its concave sides turned upwards and inwards (fig. 4, 2). Owing to this, the ischiatic arcade, formed by the posterior borders of the ischia, instead of having the usual form of a lyra, resembles an italic *S* directed from above downwards and from the right to the left. The external border is turned upwards and is very slightly concave; the internal one is articulated normally with the one of the other side, forming the ischiatic portion of the symphysis pubis (fig. 4, 3), the only one that exists in this specimen, the synostosis of the two ischia being complete.

The antero-external angle continues, without line of demarcation, with the posterior angle of the ilium and without existing between the two, as I have said, the smallest vestiges of the acetabulum. The antero-internal angle, instead of joining itself to the homonymous branch of the missing pubis, forms the anterior termination of the symphysis pubis, which in this skeleton is merely formed, as I have said, by the ischiatic portion. The postero-external angle, which forms the tuber ischiadicum, is very large, and is turned upwards, instead of outwards and forwards as usually

happens. The postero-internal angle (fig. 4, 4) forms with the one of the other side, in normal cases, the vertex of the ischiatic arcade.

The relation between the length of the ischium and ilium of the goat is, according to Chauveau and Arloing, about 70 per cent. In bones of a

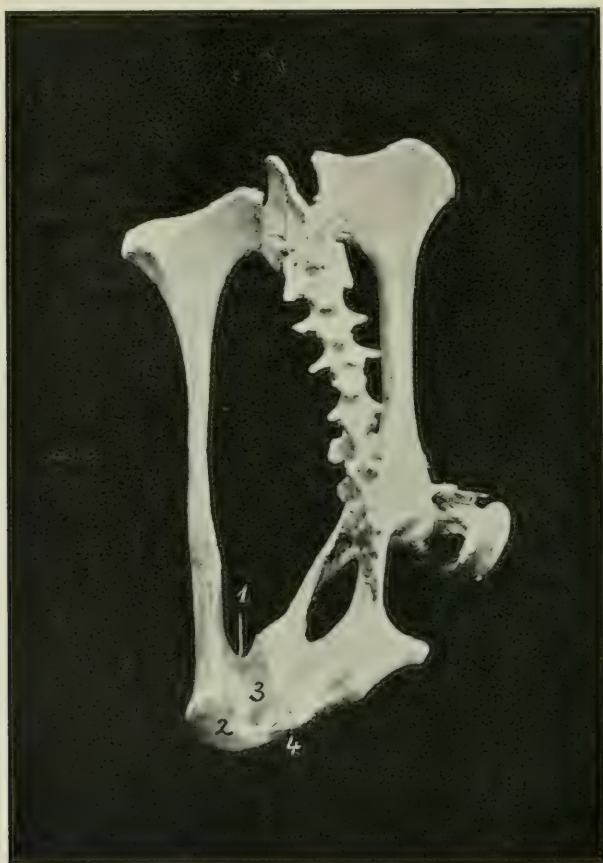


FIG. 4.—Pelvis seen from above.

normal goat I found it 64 per cent. ( $\frac{80}{125}$ ): in the right innominate bone of the ectromelic goat I found it 63.6 ( $\frac{510}{800}$ ), and on the left side 77.7 ( $\frac{500}{644}$ ).

*The Pelvis.*—On observing the superior surface, one notes that the pelvis, which is narrow and deformed, is turned backwards and to the left side. Both the crista iliaca and the iliac spines antero-superior and postero-superior on the left side are more at the back than on the right side. The apertura pelvis anterior is very irregular and continues backwards



and to the left with the ischiatic portion of the foramen obturatum on that side (fig. 4, 1).

These are some pelvimetric measures taken on this skeleton:—

Apertura pelvis anterior—sacro-pubic diameter (from the base of the sacrum to the anterior border of the right pubis)—10·5 centimetres, as much as in a normal goat: diameter bi-iliac, taken at the right acetabulum—5 centimetres (7 in normal goat).

Apertura pelvis posterior—from the apex ossis sacri to the posterior border of symphysis—13 centimetres; horizontal diameter taken at the right acetabulum—4·5 centimetres.

*Limbs.*—Both the ischiums and iliums are shorter than is usual, and consequently the innominate bones are smaller: but, in spite of that, the posterior limb is strong, and deviates somewhat towards the middle line, circumstances which helped the equilibrium of the animal. The femur is a normal length (18 centimetres from the vertex of the trochanter to the inferior surface of the external condyles), but it is thicker than usual. Its circumference, taken at the middle of the diaphysis, is 55 millimetres, whereas in normal bones it is 52 millimetres. The tibia has normal dimensions, and the leg of the skeleton has no fibula. I did not see if this was due to any congenital cause.

On the contrary, the anterior limbs are small, the bones of the various segments being shorter and thinner than in the normal goat (fig. 1). The superior borders of the scapulæ of this skeleton measure 64 millimetres, and the posterior borders 100 millimetres. I found in scapulæ of a normal goat the following measurements: 80 and 150 millimetres respectively. Thus is one able to see that the powerfulness of the posterior limb is compensated by the small development of the anterior ones.

According to Isidore Geoffroy Saint Hilaire (2), the organs, regions, and systems whose formation and development are realised later are proportionately the most variable ones. This law, called “Law of late development,” can be seen in the case which I described. It is well known that in man the ossification of the os coxæ begins independently by three centres: one for the ilium, which appears very early, in the third month of foetal life; another for the ischium, which generally can be noticed before the end of the same month; and a third for the pubis, which only appears between the fourth and fifth month, and can even not exist till the sixth (3).

Chauveau and Arloing (1) say that in the soliped class it is also the ilium which begins to ossify first; the ischium appears somewhat later, and the pubis last of all.

I have already had occasion to describe (4) another anomaly, in which



the law of Saint Hilaire could be verified. In an abnormal auditory system which I studied, I noted the agenesis of the tympanic portion of the os temporale, which is generally the last to ossify. The absence of that part brought on the absence of the auditory canal and other morphological complications of the ear.

G. Saint Hilaire says that the bi-thoracic ectromely is the most common, and after that the uni-thoracic. The bi-abdominal ectromely is rare, and still more so the uni-abdominal one. The quadrupeds, deprived of one of their limbs, move about quite well with the three remaining ones, and can even jump and run. A he-goat with uni-thoracic ectromely, observed by that teratologist in the Museum of Natural History of Paris, walked, ran, jumped, fought with other he-goats, and managed, with some difficulty, to realise sexual intercourse.

G. Saint Hilaire had already noticed that the ectromelic quadrupeds have the odd limb more strongly developed and deviated towards the middle line.

Lesbre and Forgeot (5) describe a bovine foetus, which they dissected, in which all the limbs are absent, and a dog, seven months old, in which the thoracic limbs were missing. The mother of that dog had acute chorea in the anterior limbs, and in the same litter had two bi-thoracic ectromelic pups.

The same authors refer to the skeleton of an adult cat in which the right anterior limb was missing, and to the skeleton of a kid, two months old, with absence of the right posterior limb. The posterior limb which did exist projected from the middle part of the body of the animal, whose pelvis was narrow, with the right innominate bone smaller, without acetabulum, and with premature synostosis.

In the same paper is described the skeleton of a goat, two years old, with the left posterior limb ectromelic. The innominate bone was rudimentary, with no ischium, and the ilium reduced to a small bony sheet joined to the sacrum by a ligament. There was no acetabulum, and only the pubis was well developed, in opposition to the law of Saint Hilaire. The acetabulum of the other side corresponded to the middle line. The anterior limbs of the skeleton were strong, which does not happen in my case, and the posterior limb was long, which helped the animal in its progression.

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A NOTE ON THE POSTERIOR CRUCIATE LIGAMENT OF THE  
KNEE-JOINT. By J. R. D. HOLTBY, M.B., B.S., *Chief Demonstrator of Anatomy, Trinity College, Dublin.*

SOME months ago, when working at the lower end of the femur, I noticed that the impression for the posterior cruciate ligament varied, in some cases reaching up to the articular margin in its whole extent, in others only approaching the edge anteriorly.

An examination of fresh specimens appears to furnish an explanation of this peculiarity.

If the knee-joint be opened anteriorly and the synovial covering of the cruciate bands removed, it will be found that in the majority of examples the fibres of the posterior cruciate ligament attached to the anterior and inner lip of the intercondyloid fossa lie close to the articular margin in their entire extent, whilst in other cases they only approach the cartilage edge anteriorly, the remainder of the fibres lying on a much deeper plane. This difference will, on reflecting the anterior cruciate ligament, be seen to be due to the presence in the former series of an oblique band of fibres crossing the lateral and anterior aspect of the main posterior cruciate mass to be attached to the femur in front of the hinder half of the ligament proper, the oblique band gaining insertion quite close to the articular margin.

Posteriorly these oblique fibres, which we will call the anterior oblique portion of the posterior cruciate ligament, have a somewhat Y-shaped origin. The lateral limb arises from the posterior edge of the lateral meniscus, the medial from the lateral and anterior aspect of the main cruciate mass. As the band curves round the lateral edge of the latter there is often a small bursa.

The attachment of this oblique band has sometimes been described as a root of the posterior horn of the meniscus. This mistake probably arose from the idea that this band and Wrisberg's ligament are one and the same in origin. Robert (quoted by Fick) has shown that section of the oblique band has no effect on the security of attachment of the meniscus; and, moreover, it can easily be shown that the latter is cartilage covered beyond the point of origin of these oblique fibres.

There may be two oblique strands attached to the hinder margin of the

lateral meniscus: one of these, the above-described portion of the posterior cruciate ligament, passes always in front of this ligament: the other, or Wrisberg's ligament, lies posteriorly, and its tibial attachment, if any, is directly behind and separate from that of the cruciate mass.

Parsons showed that in most mammals the hinder horn of the lateral meniscus is attached not to the tibia but to the medial femoral condyle, but this root always passes posterior to the cruciate ligament and is probably represented now by Wrisberg's band. It does not, even in

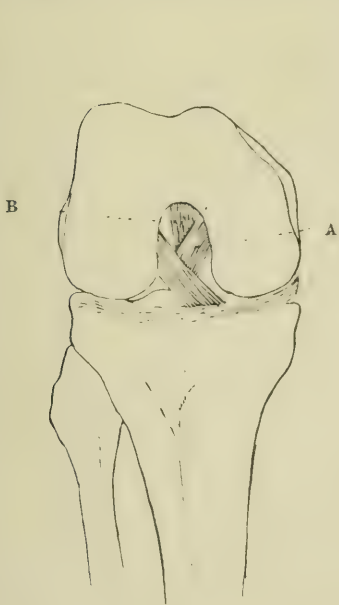


FIG. 1.—The knee-joint opened from in front and placed in the position of flexion. The synovial covering of the cruciate ligaments has been removed, showing

A, the anterior oblique band; B, the posterior cruciate ligament.

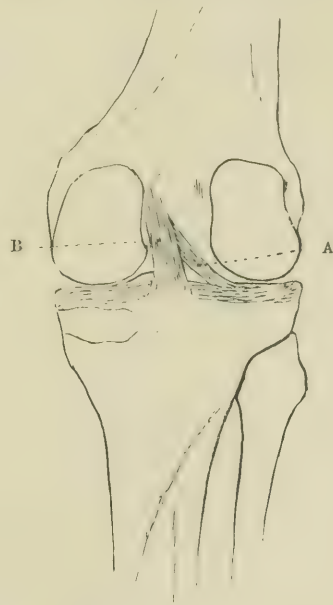


FIG. 2.—The posterior portion of the capsule of the knee-joint has been removed, and the joint placed in the position of extension.

A, lateral limb of the anterior oblique band arising from the lateral meniscus; B, the posterior cruciate ligament.

part, remain as the anterior oblique portion of the posterior cruciate ligament.

Many authors refer to these two oblique bands as being interchangeable, but I do not believe this to be the case. They are frequently found in association, as shown hereunder.

These anterior oblique fibres occur more commonly than has been supposed. Fick says he himself rarely found them, but that Barkow



states that he found an anterior oblique band in two and a posterior in three out of nine specimens examined.

In my series, the anterior band occurred in 75 per cent. of cases, and for some reason appeared to be more frequent in females than in males. It can readily be seen in young children.

It is probable that it chiefly comes into play during the lateral rotatory movement of the femur, or inward rotation of the tibia, at end of flexion, and that it then pulls the hinder edge of the lateral meniscus upwards and medially, so as to adapt its inner and hinder segment more accurately to the very oblique slope of the medial and posterior articular area on the lateral femoral condyle.

TABLE I.

	Number of Specimens examined.	Anterior Oblique Band present in.
Males . . . . .	12	8
Females . . . . .	8	8

TABLE II.—Association of the Anterior Oblique Band with Wrisberg's Ligament.

	Males.	Females.
(a) No anterior oblique band and no Wrisberg's ligament . . . . .	1	0
(b) Anterior oblique band présent. Wrisberg's ligament absent . . . . .	1	2
(c) Wrisberg's ligament present. No anterior oblique band . . . . .	3	0
(d) Both anterior oblique band and Wrisberg's ligament present . . . . .	7	6

This table shows that the presence or absence of the anterior oblique fibres is independent of the occurrence of Wrisberg's ligament.

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BILATERAL ABNORMAL RELATIONSHIP OF THE VAGUS NERVE  
IN ITS CERVICAL PORTION. By ALEXANDER GIBSON, M.A.,  
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THE presence, on both sides of the body, of the vagus nerve lying anterior to the common carotid artery, instead of posterior to it, seems to be an abnormality sufficiently rare to be worthy of record.

From the operative standpoint, the possibility of this relationship of vagus to carotid is of some importance. In ligaturing the common carotid artery, inclusion of the vagus in the ligature is, to say the least, undesirable, and might possibly lead to serious consequences.

The earliest reference to the subject is made by Dubreuil, 1847: "I ought to mention a variation occurring in the relations of this trunk (common carotid) with the pneumogastric nerve, a variation which I have seen twice, but only on the right side, viz., the nerve was placed in front of the carotid and the internal jugular."

Malgaigne, 1859, makes mention of two cases of this abnormal relationship, but does not say on which side the abnormality occurred.

Macalister, 1868, reported a case occurring in an old female subject on the right side: "The carotid was flexed sharply about half an inch below its bifurcation; across the flexure the pneumogastric nerve coursed, at first from without inwards, and then again, completely to the outside." The nerve was connected to the artery by a process of the sheath, and could not be replaced in its usual position until the connecting bands of the sheath had been divided.

Cruveilhier makes reference to a case where a candidate was asked to ligature the left common carotid artery. A large nerve trunk was found lying anterior to the artery. Further dissection proved this to be the vagus.

Poirier and Charpy, referring to abnormalities of the vagus, say: "Il peut cheminer en avant des gros vaisseaux."

Quain says: "The pneumogastric nerve has been observed to descend in front of the artery."

Morris says: "The pneumogastric nerve may run in front of the artery instead of behind it."

Sappey makes no reference to the abnormality.

Testut also omits to describe it, either in reference to the common carotid artery or the vagus nerve.

The subject of this nerve artery relationship is discussed by Argaud and Cochet, 1908. They find that at the third month, on transverse section, the left vagus is anterior to the left common carotid at the level of the cricoid cartilage. Apparently only one specimen was examined. From examination of fifty adults, they conclude that, "in the majority of cases, the left vagus is situated in front of and a little to the outer side of the common carotid artery, and is frequently found in the anterior angle which this artery forms with the internal jugular vein." In the majority of their cases, the left vagus came in front of the left common carotid artery at the level of the upper border of the thyroid cartilage.

The latest reference to the subject is by Casali, in the *Anatomischer Anzeiger*, 12th July 1911. This investigator examined thirty subjects: in eleven of these he found the left vagus nerve anterior to the left common carotid artery. Of these thirty subjects, eight belonged to early infancy or to foetal life. In all of these eight the left vagus lay anterior to the left common carotid. From this, Casali concludes that in all foetuses the left vagus lies anterior to the left common carotid, the artery at that stage of life being of smaller diameter than the nerve. He suggests that after birth the greatly increased diameter of the common carotid pushes the nerve into the position usually described, *i.e.* lateral and posterior to the artery. In support of this theory, he found that in an infant one year old the nerve was placed lateral, but not posterior, to the artery, a position which may be regarded as intermediate.

That this relationship exists only on the left side, he explains by the statement that the left common carotid artery is of smaller diameter, and is situated more deeply than is the right common carotid, although the two vagi occupy the same coronal plane.

Casali refers to the results obtained by Argaud and Cochet. He adds to their findings his own results, omitting data obtained from foetuses and very young children. The result is that of seventy-two subjects examined, eight presented the left vagus anterior to the left common carotid, *i.e.* 11 per cent. of cases; none presented the right vagus anterior to the right common carotid artery.

It would seem, therefore, that only three cases of the abnormality on the right side have been recorded, two of these by Dubreuil in 1847, and one by Macalister in 1868. In Dubreuil's cases we may infer that the relationship on the left side was as usually described. Macalister makes no reference to the left side, and the abnormal relationship on the right

side was associated with a flexure of the common carotid. The latest paper by Casali states specifically that in seventy-two subjects specially examined, the abnormality was not found on the right side. In this paper, also, an explanation is suggested which would require modification to make it explain the occurrence on the right side.

Parotid G.

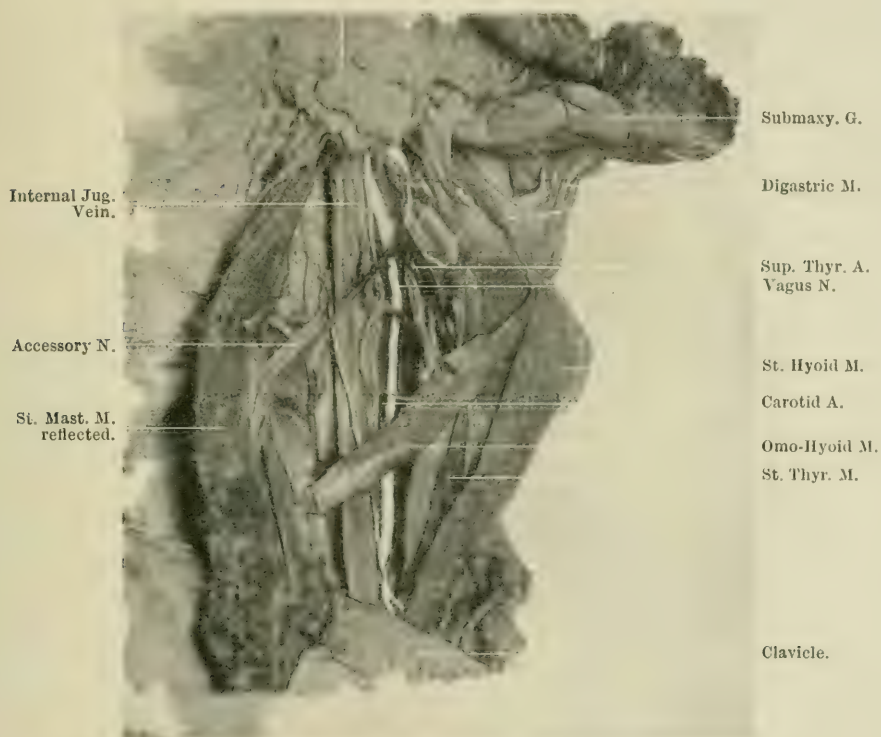


FIG. 1.

In January 1912 there was observed in the Anatomical Rooms of the University of Edinburgh a male subject, aged 59. This presented on both sides an abnormal relation of vagus to carotid.

A large nerve trunk was found lying in front of the right common carotid artery at the level of the upper border of the thyroid cartilage. The carotid artery showed no abnormal flexure. Its bifurcation into external and internal carotids occurred at the level of the hyoid bone. The nerve ran down anteriorly to the vessel until the lower limit of the neck was



reached. There it sheered off to the right, and entered the thorax by crossing the medial portion of the first part of the subclavian artery. The nerve was firmly bound down to the right common carotid artery by a process of the sheath. Not until this was dissected away could the nerve be replaced in its usual position, posterior to the artery.

The left side of the neck was at once examined, and there was found a condition of affairs corresponding precisely to that found on the right side. On both sides the nerve lay not in the angle between the internal jugular vein and the common carotid artery, but actually, for a part of its course, upon the anterior aspect of the common carotid.

In addition to numerous adult subjects, I have examined twenty-four fetuses. Of these, six were about the sixth month, two about the seventh month, one about the eighth month, and the remainder (fifteen) full time. In no case was the vagus nerve situated anterior to the common carotid artery. My observations thus do not support the findings of Casali or of Argaud and Cochet.

I desire to express my indebtedness to Professor Arthur Robinson, University of Edinburgh, for permission to record this case, and for valued assistance in referring to the literature.

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THE CHELONIAN TYPE OF GENITALIA. By FREDERIC WOOD  
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THE general arrangement of the reproductive system in the Chelonian reptiles is, of course, very well known. This knowledge is by no means recent, many of the early descriptions possessing a high degree of accuracy. The account given by Gerardus Blasius in 1674 will have to be referred to again in this paper, and it is worth quoting in full. After a good description of the other systems and organs, Blasius describes the genitalia in these words: "Penis notabilia habet corpora duo nervosa, quæ siquidem flatu distendantur, anteriora penis maximam in molem augentur, rigiditatemque summam acquirunt. cum apicis versus postica incurvatione aliqua, quo asperitates illæ, quas in parte postica seu inferiore penis notamus, liberioresque reddantur. Notabilis itidem in parte hac postica, que nempe cloacam ipsam spectat, fovea quaedam singularis, insignis satis capacitatis, dum rigidus efficitur penis canalis formam adsumens; cum in pene viam aliam observare haud licuerit, hanc seminis ejaculatione inservire judicamus; anteriora autem penis distenta utero firmius inherere. Asperitates vero adductas voluptati venereæ in foemina exitandæ dictas esse" (1).

Every modern text-book of comparative anatomy furnishes excellent descriptions of the genitalia, and one would not hope to improve on these accounts. My excuse for recording the conditions present in a variety of representatives of the order, and in defining a more or less ideal type, is that I believe such a type to be a very important one—essential in interpreting the stages met with in higher classes, and in understanding the rudiments present in some of the lower ones.

I have already outlined, in a brief manner, what has forced itself upon me as the peculiarly pre-mammalian characters of the copulatory organ. In the Arris and Gale Lectures at the Royal College of Surgeons in 1914, I drew attention to what I imagined was the importance of a proper understanding of the Chelonian stage; and since that time the examination of a wider series of types has in every way strengthened my views (2).

It has, therefore, seemed to me desirable to place on record, in connected form, an account of the Chelonian genitalia merely as a preliminary

step to a fuller study of the genitalia of the Mammals which is being undertaken.

All Chelonians lay eggs enveloped in a definite shell, and this physiological fact is a guarantee that some method of copulation must be practised, and some degree of special copulatory organ is likely to be developed. When an egg is laid "shelled," it is necessary for the spermatozoa to be conveyed to it while still within the female passages, and before the shell membrane has been deposited. Shelled eggs imply internal fertilisation, and internal fertilisation requires the development of some intromittent organ in the male.

The hard-shelled eggs of the common European tortoise are well known; the calcareous shell is completed in the oviduct, and in living specimens purchased in the London markets, eggs in all stages of calcification are almost invariably met with, although their extrusion in this country does not seem to be a very frequent occurrence.

The marine Chelonians also lay their calcareous eggs on land, and the breeding habits of *Chelone midas* are very well known in consequence of the local demand for their eggs as an article of diet. This turtle not uncommonly lays its large batch of eggs some weeks after it has been received into the tanks of the London turtle merchants. Concerning one turtle (*C. imbricata*) I am well aware that there is at least a legend that the egg-laying habit is departed from, and that the young are produced alive. I cannot assert from first-hand knowledge that this legend is untrue, nor do I know any account of the breeding habits of the hawksbill given by an eye-witness. In its breeding habits it must be, at any rate, more elusive than *C. midas*, for in a place where the two forms are equally abundant the natives know nothing, beyond this legend, of the reproduction of *C. imbricata*, when the nests of *C. midas* are familiar and much sought objects.

For the most part the eggs of terrestrial forms are elongated, whilst those of the aquatic types, both fresh water and marine, are spherical. Concerning the intimate details of the reproductive habits of Chelonians I know but few observations. Courtship, so far as I have observed it among the land tortoises, commences, as Gilbert White has expressed it, by the male walking "on tiptoe; his fancy intent on sexual attachments, which transport him beyond his usual gravity, and induce him to forget for a time his ordinary solemn deportment" (3). From this stage of activity, courtship is advanced, as I have several times observed, by the male overtaking the female and, withdrawing his head beneath the shelter of his carapace, giving the hinder part of her shell a series of short, sharp blows with the overhanging margin of his dorsal shield.



This performance is repeated at frequent intervals during several days, but at length, after a prolonged series of resounding taps upon her shell, the female is arrested.

Copulation is prolonged, and, as Owen observes "the development of the penis bears relation to the physical impediments to coitus, caused by the shape, extent, and completeness of the shell" (4).

In cloacal types of Vertebrates copulation is effected in a variety of ways. We may imagine that the most primitive method was for the cloaca of the male to be applied closely to that of the female, and for the spermatozoa to be passed from one open orifice into the other.

Such a stage is but a slight advance upon that seen in the frog, where the unshelled nature of the egg does not demand an actual internal fertilisation. The next advance may be supposed to consist in the eversion of the cloacal wall of the male, and the insertion of such an everted portion into the female cloacal orifice. Such a stage is seen in many of the more terrestrial of the Amphibia. In *Gymnophiona* the copulatory organ "simply consists of the eversible cloaca, which is regulated by a well-developed musculature" (5). In *Cecilia limbricoides* this everted portion may amount to some 5 centimetres.

In some of the Amphibia, however, copulation is still more complete. It is well known that some Amphibians have, to a great extent, emancipated themselves from their ancestral aquatic breeding-grounds, and although these forms have not adopted the habit of laying shelled eggs, they have missed out this stage, as it were, and passed direct to the culmination of the results of internal fertilisation in the production of living young. One such form is *Salamandra atra*. Of these animals Gegenbaur has observed, "Un indice d'un organe copulateur se remarque chez les Amphibiens (Salamandrines), sous la forme d'une papille faisant saillie dans le cloaque" (6). This rudiment of a copulatory organ is of interest, for it thickens and enlarges in the male during the breeding season. The condition seen in *Salamandra atra* I would regard as the prototype of the copulatory organ of the Chelonians (and the Crocodiles) as well as of the Mammals.

Although concerned only with the Chelonian reptiles, it is worth while to turn aside to note the very curious separation which exists, in the type of copulatory organs, between them and the Snakes and Lizards. There appears to be no common meeting-ground for these two types, and, although not by any means identical, the copulatory organs of Snakes and Lizards (scaled classes) have more kinship with those of the Elasmobranchs, while those of the Chelonians and Crocodiles (scutated classes) seem plainly to be elaborations of the condition seen in Amphibians.



The most generalised of the Reptiles—*Sphenodon*—is said to possess no distinct copulatory organ, and although I have had no opportunity of verifying the condition, it would seem to be comparable to that existing in *Gymnophiona*. If we accept the form of the external genitalia as our sole criterion (doubtless an extremely illogical standpoint), we may trace to the base of the Reptilian stock a type which, in its most primitive form, is akin to that of the Amphibia; and this type becomes modified in certain Reptilian orders to a condition which simulates that of the Mammals. There is, despite modifications, an obvious kinship between this type and that seen in the *Ratitæ* among the Birds, for in them also a median ventral specialised portion of cloacal wall is developed as a copulatory organ.

It is now necessary to trace the evolution of the "papilla," which, first developed upon the ventral wall of the cloaca in certain Amphibians, becomes the highly specialised copulatory organ of the Chelonians. In its simplest Chelonian form it consists of a thickening of the ventral cloacal wall; the thickening being in reality composed of two bilateral portions closely approximated to each other in the middle line; a slight median depression alone marking their bilateral disposition in the ordinary non-functionating phase.

In the Amphibians the papilla appears to be in large part glandular, and the enlargement during the breeding season is described as taking place by hypertrophy of this glandular tissue. In the Chelonia the papilla is composed of fibrous tissue containing large vessels and constituting a true "cavernous" erectile body. In its minimal Chelonian development this bilateral erectile mass stretches from the orifice of the urogenital sinus to a point not far distant from the cloacal outlet upon the ventral surface of the tail.

These two cavernous erectile thickenings are developed in the tissues of the ventral cloacal wall, and are, of course, covered by the lining epithelium and superficial layers of the cloacal wall. Between the two masses there is a median depression of the cloacal wall, a depression which leads from the orifice of the urogenital sinus to the terminal part of the cavernous bodies.

The functional rôle of such a copulatory organ is simple. The cavernous bodies become enlarged; they swell up, and their distal extremity is protruded from the cloacal outlet. With their enlargement, the groove between them deepens, and with complete erection it tends to be a closed channel rather than a mere groove (see figs. 1, 2, and 3).

The erectile bodies are obviously developed to provide an organ of sufficient rigidity to be everted from the male cloaca and to be inserted into the female cloaca, and we may at once name them as corpora

cavernosa. The groove, which in erection tends to become a closed channel, is for the conveyance of semen from the male urogenital sinus to the female cloaca, and I shall name it throughout the "seminal groove."

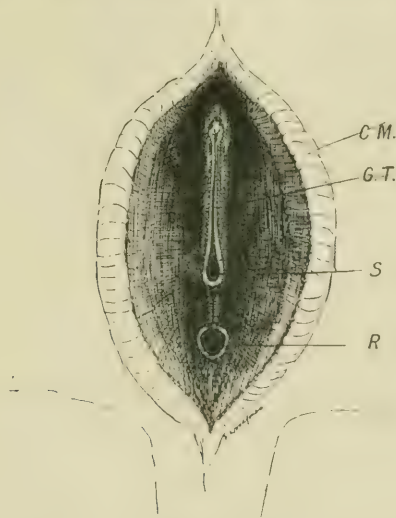


FIG. 1.—Diagrammatic view of the cloaca of a Chelonian. The cloaca is widely opened to show the intra-cloacal copulatory organ *in situ*.  
C.M., cloacal margin; G.T., genital tubercle; S, opening of urogenital sinus; R, opening of rectum.

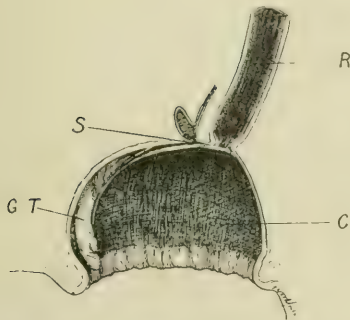


FIG. 2.—Diagrammatic view of the Chelonian copulatory organ in its quiescent intra-cloacal condition.  
R, rectum; S, urogenital sinus; G.T., genital tubercle; C, cloaca.

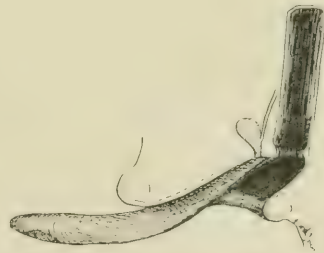


FIG. 3.—Diagrammatic view of the Chelonian copulatory organ everted from the cloaca.

In the ordinary quiescent state of the parts, the products of the male urogenital sinus are discharged from the orifice of this chamber into the cloaca, and so to the exterior. In sexual functional activity they are

carried along the groove from the orifice of the male urogenital sinus to the extremity of the cavernous bodies, and so into the female cloaca.

Such is the primitive type of the Chelonian copulatory organ; and as such it is present most nearly in its simple condition in the marine turtles. Evolution from this stage takes place by, firstly, a general enlargement of the organ, and secondly, by a greater development of that portion of it which is free of the cloacal wall. In its most primitive form the erectile mass is simply a thickening of the cloacal wall, and is incorporated in this wall throughout the whole of its length. Increasing perfection is

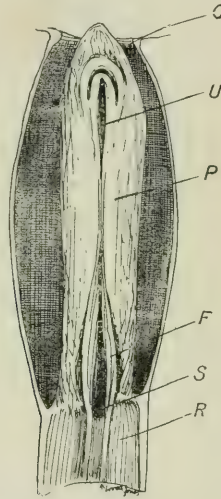


FIG. 4.—Copulatory organ of the male *Testudo tabulata*.

C, cloacal outlet; U, seminal groove; F, seminal guide;  
P, penile body; S, urogenital sinus opening; R, rectal opening.

gained by the distal portion of the organ becoming free of the cloacal wall; and in its most fully developed form a considerable portion of the body of the penis is free, both during erection and in the quiescent state.

Specialisation of this primitive type, however, takes place in several ways. The corpora cavernosa may be greatly complicated. Firstly, they may develop coiled or S-shaped reserve portions, very similar to those seen in many Mammals: these coiled portions become straightened out in complete erection, and, thereby, add greatly to the length of the functioning organ (see fig. 5).

Secondly, there may be developed within their thickness varying degrees of "peritoneal canals"—spaces which communicate with the coelom: and these may possibly help (as has long ago been suggested) in

the erection of the copulatory organ by imparting to the cavernous bodies a heightened intra-cœlomic pressure.

Thirdly, they may become generally enlarged so that they stretch cephalad to the cloacal orifice of the rectum and caudad almost to the cloacal outlet.

Again, by changes in the tissues of the ventral wall of the cloaca the seminal groove may be greatly elaborated. The first stage in this elaboration is the development over the cavernous bodies of bilateral ridges which

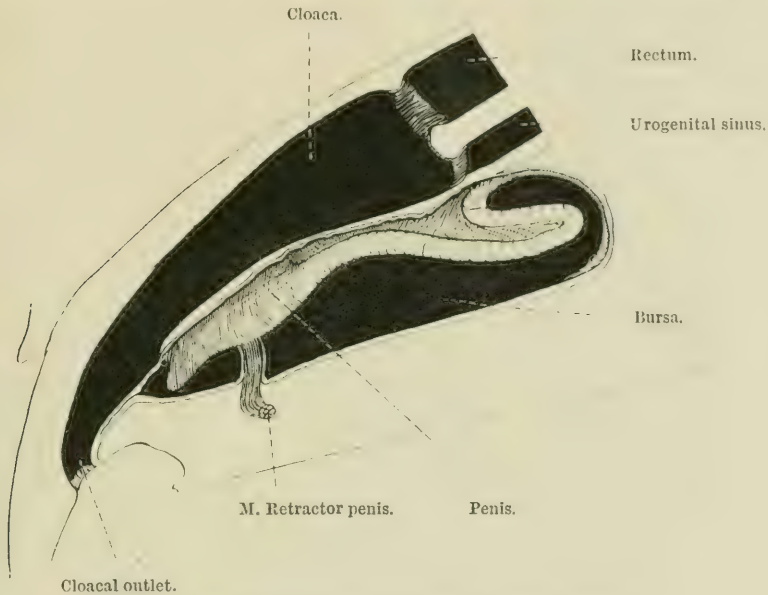


FIG. 5.—Section of the cloaca of a male *Clemmys leprosa*.

mark and accentuate the margins of the groove. These lips are coterminous with the extent of the groove, and since they help to deepen the seminal groove and to direct the semen, I shall name them throughout as the "seminal guides."

In the males of most of the terrestrial forms these seminal guides extend from (and into) the rectal cloacal opening to the extremity of the corpora cavernosa—and on this account they have been distinguished by some zoologists as the "plicæ recto-urethrales" (see fig. 6).

The next stage in the elaboration is the development of erectile tissue in these seminal guides; a stage seen well in sections of the copulatory organ of the males of most species; this erectile tissue is the prototype of the corpora spongiosa of the Mammalia.



When development has arrived at this stage, we have an intra-cloacal erectile copulatory organ which is cleft upon its free cloacal aspect, and is, in the nomenclature of human teratology, in a condition of complete hypospadias; but this hypospadiac condition is obliterated in erection by the meeting of the erectile seminal guides and the completion of the seminal canal.

Development of the corpora spongiosa goes further in most terrestrial species, and at the base of the copulatory organ a thickening occurs which

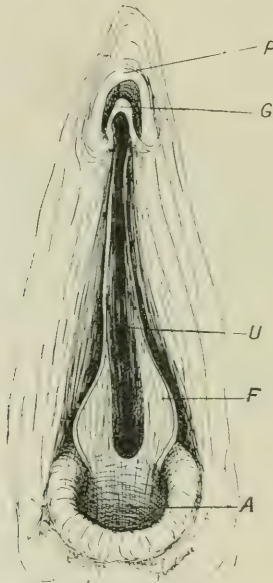


FIG. 6.—Well-developed copulatory organ of the male *Testudo elephantina*.

P, prepuce; G, glans; U, seminal groove; F, seminal guide; A, rectal opening.

is obviously the Chelonian homologue of the mammalian bulb of the corpora spongiosa. (The word “bulb” is here used for the thickening of the erectile mass, and not in its more correct—and Hunterian—sense as a synonym for the dilatation of the urethra within this thickening.)

Another specialisation of erectile tissue takes place at the distal portion of the organ, and this—the “asperitates” of Blasius—constitutes the homologue of the mammalian glans. This glans is of varying degrees of development in different species. It is more highly developed in the tortoises than in the turtles, and in the purely land-living types, as *Testudo*, it reaches its maximum degree of development (see figs. 6, 7, etc.).

When well developed, it consists of a trilobed mass of erectile tissue, the single lobe being distal and median, with the other two lobes arranged bilaterally at its base. The cloacal mucous membrane covering this glans is, as a rule, deeply pigmented. The seminal groove passes between the

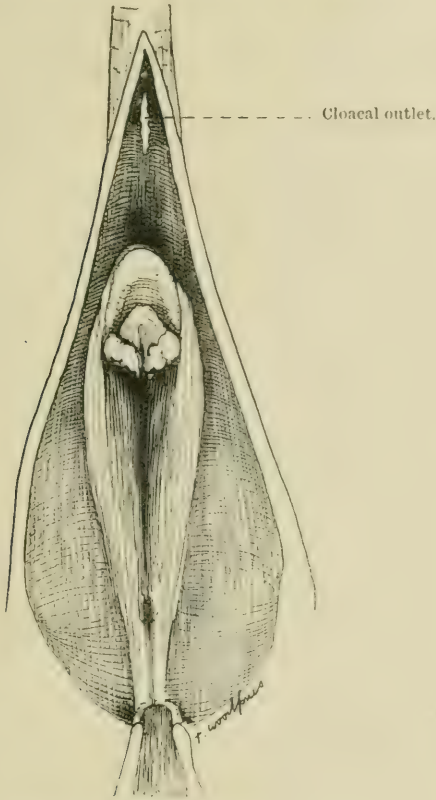


FIG. 7.—The cloaca of a male *Clemmys leprosa* opened from its dorsal aspect to show the structure of the copulatory organ.

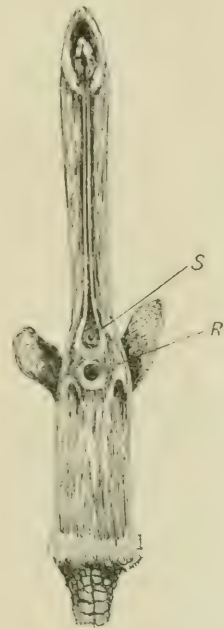


FIG. 8.—Copulatory organ of the male *Emys orbicularis*. The cloaca is opened along its lateral margins and the ventral wall and copulatory organ turned upwards.

S, urogenital sinus opening; R, rectal opening.

two basal lobes (these being in reality the expanded extremity of the seminal guides), and it grooves the distal lobe. Distal again to this median lobe is an erectile mass, usually bluntly pointed, which is the termination of the copulatory organ and is free of the cloacal wall. This free tip is surrounded by the redundant mucous membrane of the cloacal wall in such a way as to be partly concealed in the quiescent state. The mucous membrane reduplication which covers the distal portion of the quiescent

glans may be distinguished as the prepuce, and from this prepuce the organ is protruded in erection.

The copulatory organ of the female is in all its details similar to that of the male, except only that it is in every way less developed (see fig. 9).

The clitoris does not extend so near to the cloacal opening; it cannot

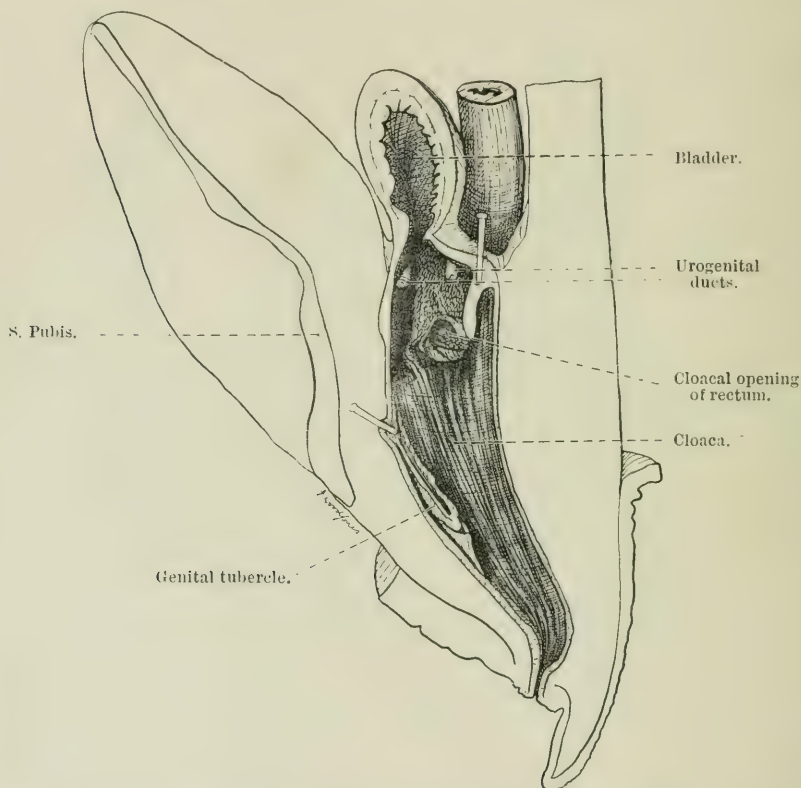


FIG. 9.—The cloaca and copulatory organs of a female *Chelone midas*.

be extruded from the cloaca, nor can it be seen by external examination of the cloaca in the living animal of any species I have examined (see fig. 10).

Although a somewhat rudimentary structure, this female copulatory organ is perhaps not to be classed in the same category as such vestigial survivals as the male nipple, for it is not unlikely that it possesses some function in copulation. In these animals in which the seminal guides do not unite anatomically at their free edges, it is possible that the seminal groove of the female copulatory organ may assist the seminal

guides of the male in forming a complete seminal channel during copulation. It would seem quite possible that there is a mutual adaptation between the male and female copulatory organs in these animals by

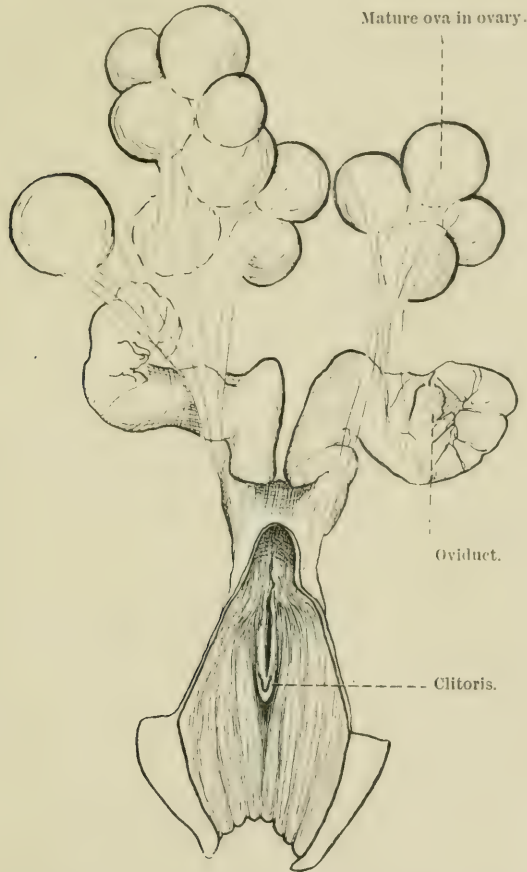


FIG. 10.—Ovaries, oviducts, and cloaca of a female *Testudo ibera*.  
The cloaca is opened from its dorsal aspect to show the copulatory organ.

which an opposition of their primitive dorsal surfaces assists in perfecting a channel for the passage of semen. With all the modifications displayed in the mammalian orders (which will be considered elsewhere) this approximation of the primitive dorsal surface of the male copulatory organ to the similar surface of the female is maintained.

The secondary adaptations of the Chelonian copulatory organ are



simple. It is erected and extruded doubtless by vaso-motor influences acting upon the vessels of the erectile bodies as in the Mammals. It is brought back again to its normal intra-cloacal station by special muscles, the retractors of the penis, which are inserted to its ventral aspect and run as ribbon-like bands around its sides to gain origin from the ischium (see figs. 11 and 12). The cloaca is under the control of the sphincter

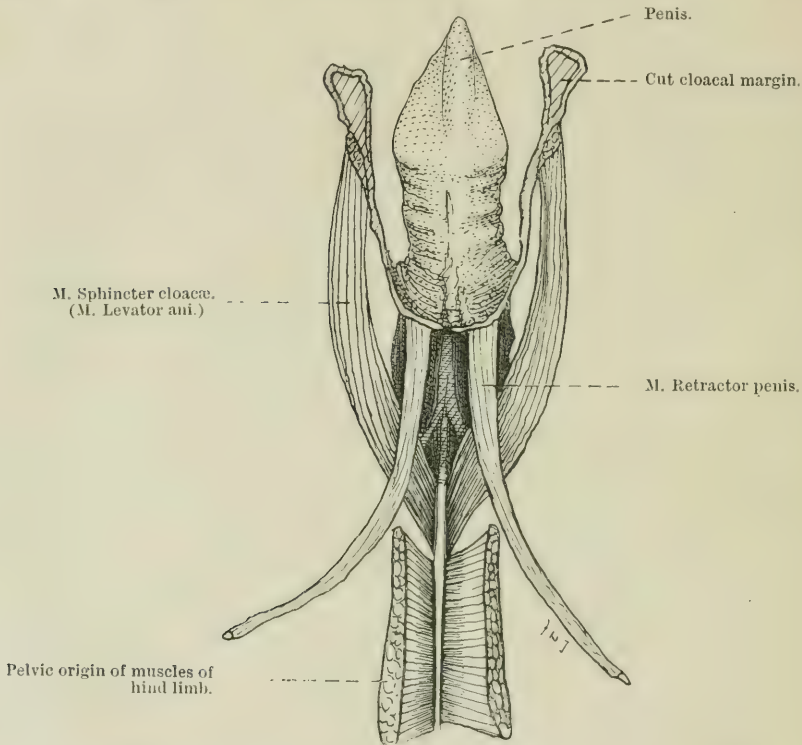


FIG. 11.—Penis and muscles of male *Testudo graeca*, dorsal aspect.

cloacæ, which is the Chelonian homologue of the levator ani, and is attached on the one hand to the ventral portion of the pelvic girdle, and on the other to the vertebral skeleton of the tail.

In order to provide for a more complete extrusion of the copulatory organ, and to permit its free movement within the limits of the cloacal wall, a large subcloacal bursal space is developed in many species. The bursa is interposed between the cloacal wall and the ventral musculature of the hind limbs, and into it the penile body and the coiled ends of the corpora cavernosa project in the quiescent state (see fig. 5).

So much of description and illustration will serve to cover the general features of the genitalia of the Chelonian reptiles. This description and illustration I have considered necessary in a preliminary study, since it seems to me that no proper understanding of the ontogeny of the mammalian external genitalia may be come by until some clear idea of the phylogeny of the process is arrived at. The early phases of development, even of the human external genitalia, are very reminiscent of the adult Chelonian condition, and I think it may be laid down that: (1) appearing first in the Amphibia, the type of copulatory organ with which we are dealing is in its minimal development a mere intra-cloacal papilla—this papilla being developed upon the ventral wall of the cloaca; (2) that in Chelonians (and in Crocodiles) this papilla becomes specialised,

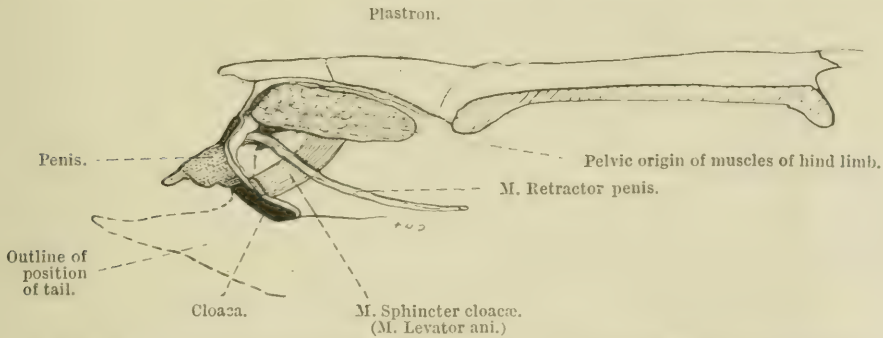


FIG. 12.—View from the left side of the copulatory organ of a male *Testudo graeca* and its associated muscles.

in the ways specified, as a highly developed copulatory organ: although (3) in the Lizards and Snakes an altogether different type of copulatory organ is developed; (4) that considered on broad lines this Chelonian type of copulatory organ presents many striking resemblances to the embryonic condition seen in Mammals.

I will refrain from making any further comparison between this type of genitalia and those types seen in the mammalian orders, for this can only be done after the types prevalent in the different orders have been submitted to ordered review. I would, however, point out that the functional eversion of the intra-cloacal genital tubercle, which in Chelonians only accompanies sexual activity, becomes the prototype, under varying conditions, of normal mammalian development; and I would further note that an intra-cloacal genital tubercle but little modified from the Chelonian condition exists as an adult permanency in some Mammals, not only among the Prototheria, but even among the Eutheria.

If we may make any deductions at all from the type of the external genitalia, it would therefore seem probable that the mammalian stock arose early from some basal meeting-point of the Amphibians and the scutate Reptiles in a form in which cloacal eversion had proceeded to the specialisation of a portion of the ventral cloacal wall as a copulatory organ.

Towards the purchase of material used in this research assistance has been afforded from the "Dixon Fund" of the University of London.

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AN ANOMALOUS CORONARY SINUS. By W. K. HUTTON, M.A.  
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of Glasgow.*

THE heart which exhibited the abnormality to be presently described was found in a storage jar in the Anatomical Department of the University of Glasgow. It was one of a number of old specimens which had evidently been obtained, at various times, in the dissecting room, and then put aside for more detailed examination. The organ had been removed from the body along with the left innominate vein, the vena cava superior, and part of the root of each lung.

A slender left superior vena cava was present; its course and relations were those usually found in cases of persistence of this vessel. Traced from its union with the left innominate vein, about 4.5 cm. from the junction of this trunk with that of the right side, it passed caudally, ventral to the root of the left lung, and then dorsal to the left auricular appendage; thereafter, rapidly becoming considerably dilated, it coursed obliquely over the left atrium, to end in continuity with the coronary sinus.

Above the root of the lung it received a small tributary vein which may have been part of the left posterior cardinal.

The diameter of the normal vena cava superior, just central to the point where the azygos vein joined it, was, in the distended state, 3.5 cm.; that of the left cava, at a corresponding point, 5 mm. The coronary sinus was large: its length, measured from the point of entrance of the vena cordis magna to its right extremity, was 3.8 cm.; its diameter at the widest 1.5 cm. Both the sinus and the veins of the heart were filled with stone-hard blood clot, and when this was with difficulty removed, the following condition was found.

The great vein of the heart and the marginal vein of the left ventricle each emptied into an ovoid, sinus-like dilatation (see fig. 1),—2 cm. long by 1 cm. wide—the long axis of which lay parallel to that of the coronary sinus. The marginal vein joined this confluence at a right angle, and a fold resembling a small and imperfect valve lay at its ostium; the vena cordis magna opened at the left extremity of the enlargement, and in this part of its course was straight; when traced distally in the atrio-ventricular



sulcus it was found to be very tortuous. No valve guarded its mouth, but at the opening of the common dilatation into the coronary sinus there was

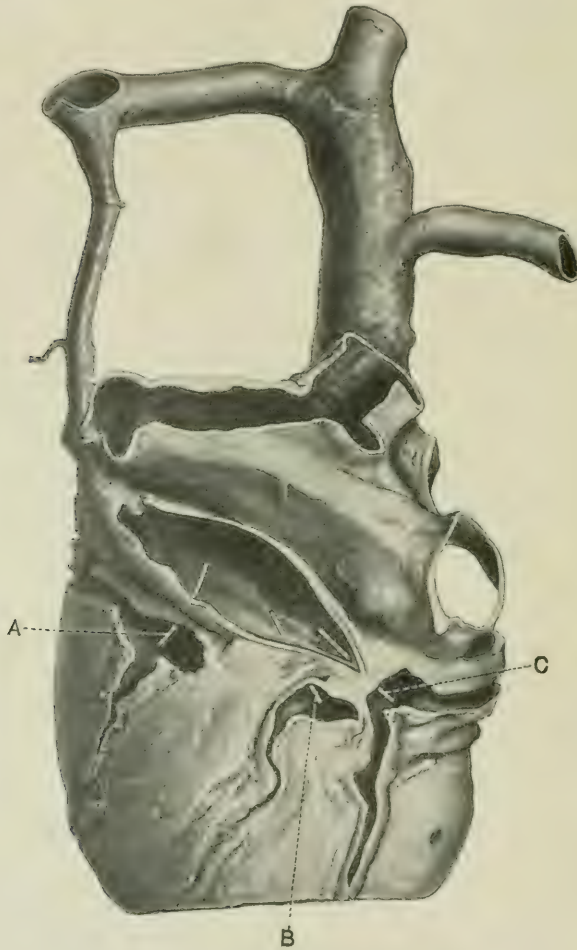


FIG. 1.—View of heart from behind.

A, bristle passed into sinus from confluence of vena magna and marginal vein; B, bristle passed into sinus from dilatation of posterior vein; C, bristle passed into sinus from confluence of vena media and right cardiac vein.

a complete two-cusped valve, which was unfortunately partially destroyed in the attempt to remove the blood clot.

A posterior vein of the left ventricle, of fair size, ended in a similar, but smaller, varicose swelling that opened, about the middle of its length,

into the coronary sinus: an imperfect, single-cusped, semilunar valve lay at the orifice.

The vena cordis media and the small, or right, vein of the heart—the latter, in this case, almost of the calibre of the vena media—joined one another to form a confluence before opening into the narrowed and somewhat pointed right extremity of the coronary sinus: the aperture was guarded by a competent two-cusped valve.

On the atrial wall of the sinus at its termination was an oval depressed area (A, fig. 2), about 10 mm. by 5 mm., its long axis coinciding with that of the sinus. This area corresponded in position to the usual opening of the coronary sinus into the right atrium, but such a communication was here

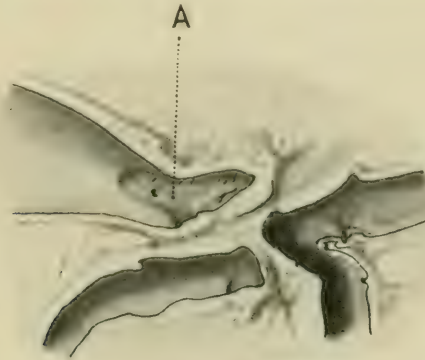


FIG. 2.—Right extremity of the sinus coronarius. (Natural size.)

A, the pitted, sunken area.

entirely absent; the floor of the depression had upon it a number of little pit-like markings, but trace of opening there was none.

In short, in this instance, the left horn of the sinus venosus,—the usual atrial aperture occluded—the left duct of Cuvier, and the central segment of the left vena cardinalis anterior, acted as a continuous efferent channel for the venous blood of the heart, carrying it to the left innominate vein, and so over to the right side.

On examining the right atrium there was found, in the usual position of the ostium of the coronary sinus, a shallow circular depression (B, fig. 3); its margins were ill defined, save dorsally, where it was bounded by that lower portion of the limbus fossæ ovalis which is derived from the inflection of the wall of the sinus venosus that separates the coronary from the caval segment of the right venous valve.

The floor of the depressed area was thin and was marked by shallow

grooves and pits: its extent could be covered by the tip of the little finger, and it abutted against the sunken pitted area already described as existing on the atrial wall of the coronary sinus.

Only the basal part of the Eustachian valve of the vena cava inferior persisted. On the other hand, on the septal wall of this vessel there was a very considerable remnant of the left venous valve (A, fig. 3); this had the form of a reticulated membrane, attached by one edge to the caval wall,

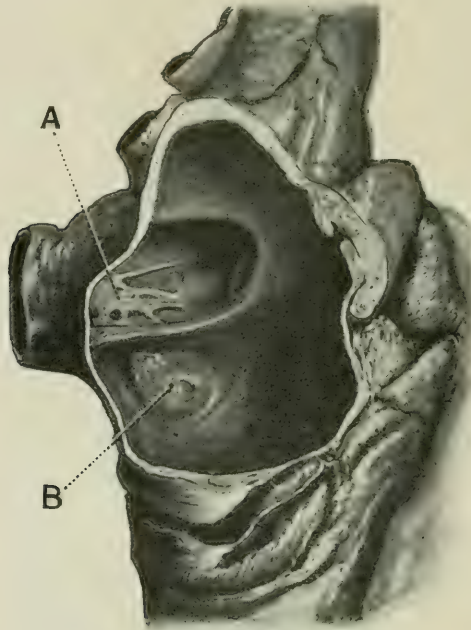


FIG. 3.—Right atrium, opened.

A, caval remnants of left venous valve; B, depressed area corresponding to position of the normal sinus opening.

and by the other, through the intermediary of delicate strings and bands, to the base of the septum ovale. Near the mouth of the vena cava superior a distinct semi-lunar endocardial flap, concave caudally, and covering the mouth of a small vein, probably represented another portion of the same valve.

It seems plain that the occlusion of the normal atrial opening of the sinus coronarius must have occurred at some period of development subsequent to the formation of that transverse connexion between the anterior cardinal veins which persists as the vena anonyma sinistra of the

adult, but before the continuity of the left duct of Cuvier and proximal portion of the left anterior cardinal vein was wholly interrupted. But while this is evident, the cause of the closure itself is by no means obvious, or easy of solution on embryological grounds, and, on the other hand, there seems to be no need in this case to postulate some ante-natal diseased state, as the heart was in other respects normal.

There appear to be two possible explanations of the anomaly under consideration; these are put forward in this note with all reserve, in recognition of the fact that our knowledge of the developmental changes attending the partial absorption of the sinus venosus into the atrial portion of the heart is as yet incomplete.

The position of the depression, described as existing in the right atrium, corresponds accurately with that of the normal sinus opening, and, further, is separated from the pitted area on the sinus wall by only a thin sheet of tissue: its situation and appearance give the impression of the occlusion of an aperture by the interposition of a tissue layer, rather than by a process of stenosis, and I suggest that this partition between atrium and sinus is either (1) a composite structure, the result of fusion between the coronary segments of the right and left venous valves, or (2) results from the presence, in earlier development, of an unusually voluminous Thebesian valve which has eventually fused with the margins of the opening of the sinus.

(1) Normally the lowermost, or ventricular, segment of the left venous valve disappears completely by fusing with the atrial septum, while that of the right persists as the coronary valve of Thebesius. If one suppose that in the case in point, the lower part of the left valve persisted not only in its caval division (as it has) but in its coronary segment as well, it seems not unreasonable to believe that such a complete valvular protection for the opening of the coronary sinus would be formed as might, when the pressure in the right atrium rose as a result of the augmented blood-intake due to the formation of the left innominate vein, become almost too effectual—a double flap valve.

The resulting back pressure in the coronary sinus would then tend to prevent the normal obliteration of the venous path between the left anterior cardinal vein and left duct of Cuvier.

At birth, the difference of pressure in atrium and sinus would be still further increased by the closure of the foramen ovale, and a fusion between the right and left segments of the coronary valve—similar to that which takes place between the septum primum and septum secundum—might occur, and lead to the complete occlusion of the coronary orifice.

(2) The normal sinus opening is, when the valve of Thebesius is well



developed, a triangle with two long sides,—the sinus septum and the coronary valve respectively—and its rhythmic closure is, in all likelihood, effected by the apposition of these two margins. If, however, the Thebesian valve were unusually voluminous, it is conceivable that it might act as a flap valve with results analogous to those just enumerated in the first tentative explanation of the abnormal condition under consideration.

As to the sinus-like confluences found in connexion with the veins of the heart, it seems not unreasonable to associate their presence with a certain amount of venous stasis that may be imagined to have existed throughout life. Such dilatations are found even in hearts with a normal coronary orifice—according to Poirier and Charpy the vena cordis magna was found to possess a proper sinus twice in 130 cases. Varicosity of the cardiac veins would seem to be a corollary to venous back pressure in the coronary sinus from whatever cause arising, since the valvular mechanism is anything but complete.

In the literature on the heart there are recorded but two other undoubted examples of occluded coronary ostium, for the brief notice of the case of Le Cat (1) 1738, merely states that in a child eight days old the coronary veins were found united as a single trunk, which, without entering the right auricle, emptied into the left subclavian vein; it is, of course, quite probable that the “single trunk” was the coronary sinus.

In 1885 W. Gruber (2) reported that, in an example of persistent left superior vena cava, occurring in a fifty-year-old man, the coronary sinus, with which the trunk was continuous, ended blindly without an atrial opening. The specimen was very similar to that described above. The great vein of the heart and marginal vein of the left ventricle opened into a common sinus; another dilatation was common to the vena media and v. parva; but the posterior vein of the left ventricle showed no enlargement. The ostia of the veins at the confluences, and the openings of these latter into the coronary sinus, were valved. In the right atrium, in place of the usual coronary aperture, was a groove, 14 mm. long and 7 mm. deep, that led into a *cul-de-sac* 6 mm. in depth: the free membranous atrial margin of this opening Gruber tentatively calls “Thebesian valve.”

Anton Siding (3), who seems to have been unaware of Gruber's note of 1885, described in 1896 the conditions met with in the heart of an adult man removed at a *sectio* and sent to Professor Hochstetter. In this case also the left end of the coronary sinus was connected to the vena anonyma sinistra by a vessel 5 mm. in diameter. After receiving the great vein of the heart the coronary sinus, when traced to the right, was found to end in a blind conical extremity considerably (1.5 cm.) short of the site of its usual opening into the right atrium. Into the blind end of the sinus opened the

vena cordis posterior, which was constricted just distal to its termination. In the right atrium, and in the usual position of the normal sinus opening, was a narrow (5 mm. wide) aperture guarded by a feebly developed Thebesian valve. The opening led into a blind sack, about a centimetre in length, which extended as far as the occluded end of the coronary sinus.

Gruber's and Siding's cases resemble one another, and differ from the writer's, in that in both there was a definitive *cul-de-sac* in the atrium,—in the one smaller, in the other larger—occupying approximately the position of the normal sinus opening, and plainly representing some part of the right end of the coronary sinus. In both also a trace of the Thebesian valve existed, so that the suggestions put forward above to account for the occlusion in the present case will not hold good for these instances, which still remain unexplained.

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## CONGENITAL ABSENCE OF THE APPENDIX OF THE CÆCUM.

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CONGENITAL absence of the caecal appendix is an extremely rare abnormality. R. J. Berry, writing in the *Anatomischer Anzeiger* in 1895 (1), after having reviewed the literature on the anatomy of the appendix up to that date, and having reported 100 cases of his own, states that "some authors have described total absence of the appendix; I do not, however, believe that the appendix is ever absent except as the result of a previous excision." Later, in 1907 (2), the same authority refers to a specimen belonging to Professor Fawcett, and writes: "The fact remains that it is the only case on record of congenital absence of the appendix vermiformis."

In the systematic examination of 1352 subjects, in which special attention was given to the anatomy of the cæcum and appendix, there was only one case in which the appendix was absent, namely, Fawcett's.

	Number of Cases examined.	Absence of Appendix.
Monks and Blake (3) . . . . .	641	0
Fawcett and Blatchford (5) . . . . .	350	1
Ribbert . . . . .	161	0
Berry (2) . . . . .	100	0
Treves (14) . . . . .	100	0
	<hr/>	<hr/>
	1352	1

Other undoubted cases of congenital absence of the appendix have, however, been recorded by Zuckerkandl, Bryant, Huntington, Meckel, Robinson, and others. I have myself seen three specimens. Two of these are in the Museum of the Royal College of Surgeons, England: Specimen 549 of the Teratological Series, described in the catalogue as "Part of the ileum and cæcum of a human foetus in which the appendix is absent and the cæcum is very short," presented by Sir J. Bland Sutton; and Specimen 549-11, presented last year by Dr E. A. Chill. In this specimen also the cæcum was rounded and very short. It occurred in a new-born child, in which there was also an epi-cephalocele. The third specimen (fig. 1),

which forms the subject of this communication, was discovered in the Anatomy Department at King's College, University of London. It occurred in a woman who was certified to have died, aged sixty-three, from arterial sclerosis and heart failure. There was no scar in the abdominal wall, nor were there any signs of inflammation in the region of the cæcum. The cæcum was in the usual situation, and was normal in



FIG. 1.—A symmetrical type of cæcum, with absence of the appendix.

size and form. It was completely covered by peritoneum. The "tæniæ coli" converged to a point, on the medial and posterior aspect of the cæcum,  $1\frac{1}{4}$  inches below the ileo-cæcal junction. No trace of an appendix was, however, visible from the outside. On examining the mucous membrane lining the interior of the cæcum, a small patch of what appeared to be adenoid tissue was found opposite the point of convergence of the three tæniæ coli, and in the position in which one would expect to find the orifice of the appendix.

The distal end or fundus of the cæcum was formed by a sacculaton



which lay to the right of and below the point previously mentioned to which the longitudinal muscular bands converged. This case therefore differs from those described by Huntington; in one of which the cæcum was round and globular and the muscular bands converged to the lowest point of the pouch, and a second in which the cæcum turned upward and to the left, and ended in a sharp point, to which several lobes of epiploic fat were attached.

The very rare occurrence of total absence of the appendix is a matter of some surprise. On considering the subject from the standpoint of comparative anatomy, one would expect that an organ which is absent in such a large number of orders and species of vertebrate animals, and only present in higher types (anthropoid apes, certain rodents, and the wombat), would frequently be absent in man.

Vestigial structures are usually, though not always, variable in the extent of their development, and are frequently found to be absent altogether. This is especially the case when the structure or organ has no apparent functional importance. The fact that although the cæcal appendix varies very considerably in its length, form, and disposition, it is so rarely absent, supports the views put forward by Berry, Keith, and others regarding its functional importance.

From the standpoint of ontogeny, one would also expect congenital absence of the cæcum and appendix to be a much more frequent occurrence than it is. In a human embryo of 7.5-mm. length (Harvard College) the cæcal diverticulum is recognisable as a slight swelling on the distal limb of the intestinal loop. In an embryo of 17 mm. (Mall) this bulging is more pronounced and forms a rounded swelling, such as is seen in Specimen 629, R.C.S. Eng. In a later stage (in an embryo also 17 mm. in length) it becomes conical. Between 40 and 50 mm. a narrower distal part which will become the appendix can be distinguished from a wider proximal part which will become the cæcum. It is not, however, until after birth that a sudden diminution in the calibre of the gut marks off the root of the appendix from the cæcum, which is at this stage symmetrical in form, the appendix coming off from its lowest point. The asymmetrical form is not developed until a few years after birth.

Arrest of development may occur at any of these stages and give rise to:—

“Absence of the cæcum and appendix” (Robinson); “Rudimentary cæcum without appendix” (Sutton, Chill); “A cæcum having a blunt conical form without appendix” (Huntington); “A cæcum having a rounded symmetrical form, with the longitudinal muscular bands converging towards its apex, but without appendix” (Huntington); “Asymmetrical form of cæcum without appendix” (Author).

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A CASE OF CONGENITAL ABSENCE OF THE LEFT KIDNEY  
AND URETER. By REGINALD J. GLADSTONE, M.D. Aberd.,  
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CONGENITAL anomalies of the urino-genital system are of interest not only as teratological curiosities, but they are also of interest to the embryologist on account of the light that they sometimes throw upon normal developmental processes. Further, as in the case described below, they frequently have a very special and important bearing on surgical practice.

DESCRIPTION OF CASE.

Complete absence of the left kidney and ureter was discovered during the dissection of a male subject in the Anatomy Department, King's College, London.<sup>1</sup> The man, who was excessively fat, was certified to have died from chronic bronchitis, aged 56. The right kidney (fig. 1) was normal in position, and, as is usual in cases of single kidney, was greatly enlarged. It was rather more than double the average weight of the kidney in the male.

The measurements and weight of the "single kidney," compared with the normal organ, are as follows:—

	Single Kidney.	Normal Kidney.
Length . . .	5 $\frac{3}{4}$ ins. (150 mm.)	4 $\frac{1}{4}$ ins. (105 mm.)
Width . . .	2 $\frac{7}{8}$ " (72 " )	2 $\frac{1}{2}$ " (60 " )
Thickness . . .	2 $\frac{1}{4}$ " (55 " )	1 $\frac{3}{4}$ " (30 " )
Weight . . .	11 oz. (315 grm.)	4 $\frac{1}{2}$ oz. (130 grm.)

The right kidney was elongated in the vertical diameter, and distinctly lobulated, but was otherwise normal in appearance. Both suprarenal bodies were present, and they were normal in size and position. The left, however, differed in form: for, owing to absence of the left kidney,

<sup>1</sup> I have to thank the students who were engaged in the dissection of the subject, Mr H. O. Gunewardine and Mr A. M. G. Mishad, who first drew my attention to the defect.

the upper pole of which normally exerts pressure on the under surface of the suprarenal body, this surface, instead of being concave, was convex.

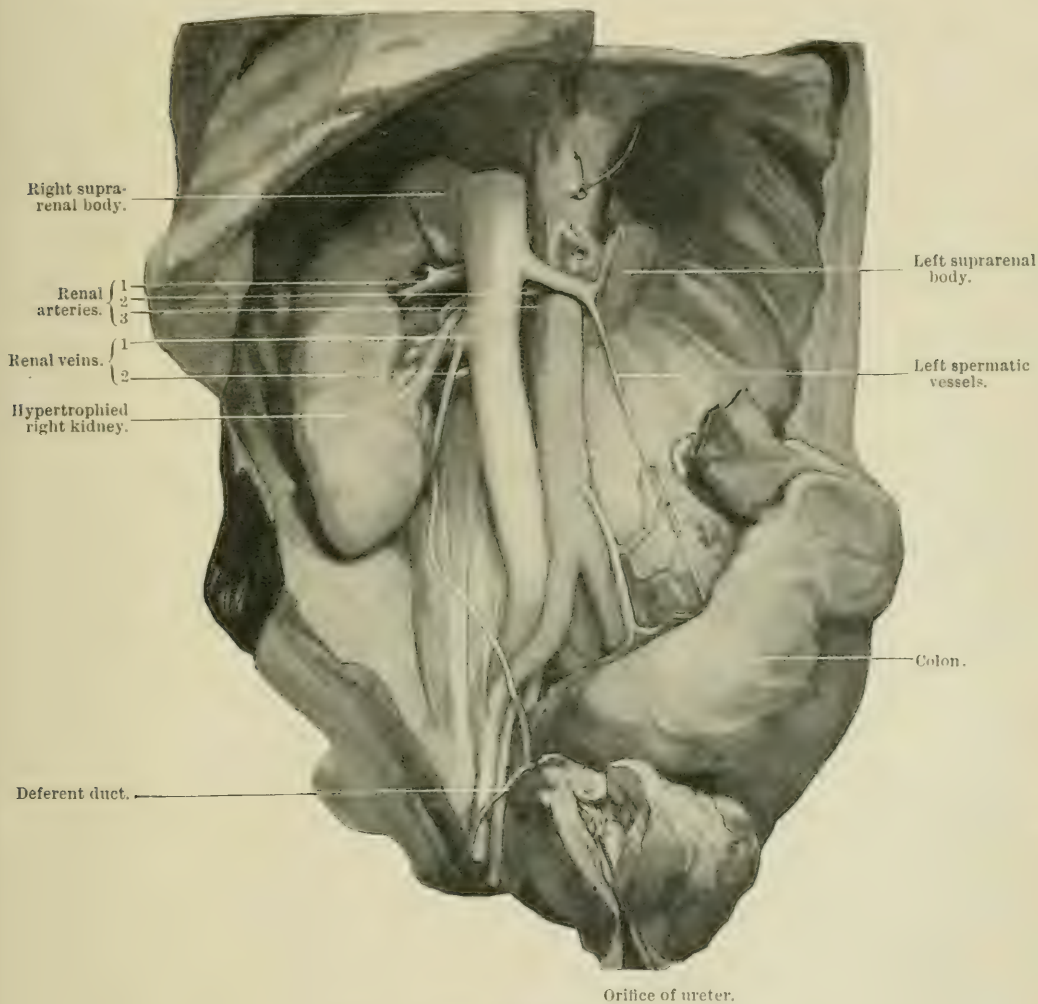


FIG. 1.—Absence of left kidney and ureter.

The ureter on the left side was completely absent, and there was no indication of a left ureteral orifice in the interior of the bladder. The pelvis of the right ureter was larger than usual, but in other respects it appeared to be quite normal.

The testis, epididymis, deferent duct, and seminal vesicle of the left



side were present but imperfectly developed. The veins of the spermatic cord were large and somewhat varicose. The cavity of the tunica vaginalis was obliterated. On section, the testis appeared to the naked eye white and fibrous. It was dense in consistence, and the tubules appeared to be imperfectly developed, and imbedded in dense fibrous tissue. The epididymis appeared to be formed almost entirely of a venous plexus supported by a loose connective tissue. The deferent duct was represented by a thin fibro-muscular band, which was with difficulty distinguished from the other constituents of the cord. It pursued the normal course, and terminated in the usual position at the base of the prostate gland by joining with a fibrous cord representing the duct of the seminal vesicle. The left seminal vesicle was, however, quite rudimentary, and no lumen could be recognised in it; nor could the opening of the common ejaculatory duct be found in the floor of the prostatic urethra.

The bladder was contracted and its walls greatly hypertrophied. As previously stated, only one ureteral orifice, the right, was present. The hypertrophy was obviously due to urethral obstruction. There was, however, no definite stricture, but rather a general narrowing of the canal, which was sufficiently marked to prevent the passage of a medium-sized sound. Whether the small size of the canal was a congenital stenosis, or the result of inflammation, it is difficult to decide, more especially as I have been unable to obtain any history of the case. As, however, there were no obvious signs of inflammation, I am inclined to regard the small size of the urethra as a congenital defect associated with imperfect development of the left half of the urogenital sinus.

#### MICROSCOPICAL APPEARANCE OF A LONGITUDINAL SECTION OF THE TESTICLE.

The organ was cut entire, stained with hæmatoxylin and counterstained with eosin. The outer fibrous tunic (t. albuginea) was greatly thickened. The substance of the organ (fig. 2) did not show the normal subdivision into compartments or loculi, by septa converging from the periphery to the mediastinum, but consisted of an irregular network of coarse bands, in the meshes of which the seminiferous tubules were embedded. The tubules differed markedly in appearance in different parts of the organ. In some parts the epithelium of the tubules had entirely disappeared, and the walls were greatly thickened, so that the lumen was reduced to a mere chink. Some tubules, on the other hand, were more or less completely filled with epithelium, the cells being mostly large, and rounded or polygonal in shape. They contained large spherical nuclei, the chromatic

elements of which stained deeply with hamatoxylin. Scattered about in the region of the mediastinum and between the tubules were other cells of an epithelial type; these, the "interstitial cells," formed irregular

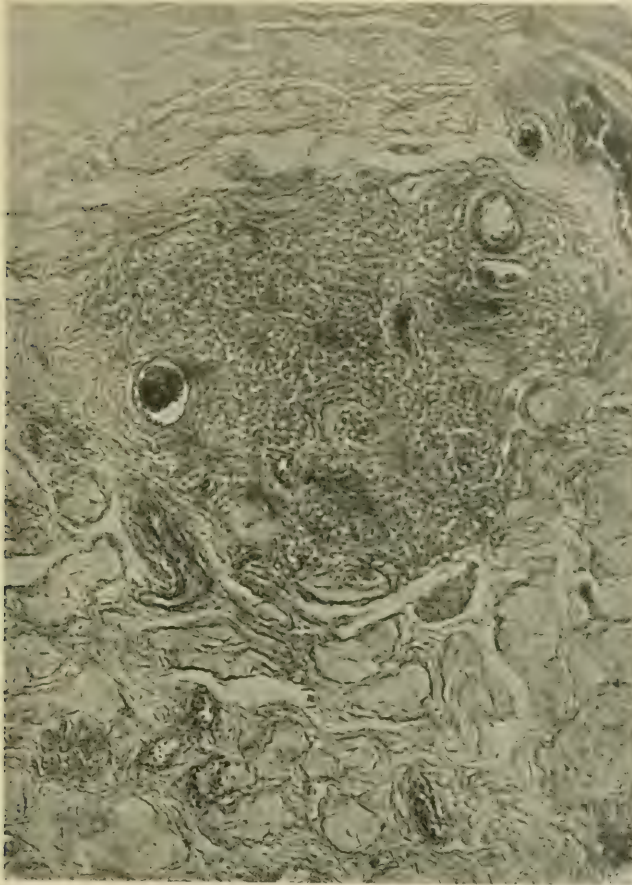


FIG. 2.—Section through left testicle from case in which left kidney was absent, showing imperfect development of seminiferous tubules and group of interstitial cells.

groups, which, owing to the degeneration of the epithelial cells in the tubules, appeared more than usually conspicuous.

In the epididymis the tubules were large and replaced by a vascular plexus. The walls of the tubules were greatly thickened, and the epithelium degenerated.

Dr Shattock, who very kindly examined one of the sections for me,

stated that the condition was very similar to that of an undescended testicle, and that he believes the thickening of the walls of the tubules to be due to irritation produced by toxic products from the degenerating epithelium.

#### ARTERIES.

The left renal artery was entirely absent. The right kidney received three arteries, which arose close together from the abdominal aorta. They occupied a normal position behind the inferior vena cava. The first or highest of these was given off at the level of the superior mesenteric artery. It supplied the upper part of the organ and a branch to the right suprarenal. One of the main terminal branches entered the anterior surface of the kidney above the hilum: another passed into the upper part of the hilum. The second and third branches arose from the right side of the abdominal aorta, one in front of the other, and both of them about half an inch below the level of the first. The second passed in front of the renal vein and pelvis of the ureter, the third behind both. They supplied the middle and lower part of the kidney.

The left suprarenal body received its blood-supply from the left inferior phrenic, the aorta, and the left spermatic arteries.

The right suprarenal body was supplied by the right inferior phrenic, aorta, and highest right renal artery.

There were two left spermatic arteries; one arose at the level of the superior mesenteric artery from the left side of the aorta, the other about half an inch below this from the same side of the aorta. They joined below to form a single vessel.

#### VEINS.

The "left renal" vein was represented by a small trunk formed by the union of the left suprarenal vein with the left spermatic vein. The suprarenal was joined by the left inferior phrenic vein. The main vein received a small tributary from the second left lumbar vein. This vessel probably represented the communication of the left posterior cardinal vein with the transverse anastomosis joining the subcardinal and posterior cardinal veins: this anastomosis normally forms the terminal part of the left renal vein.

Two right renal veins were present, a larger one above, which joined the inferior vena cava just below the level of the vessel representing the left renal vein, and a smaller vein below, which joined the inferior vena cava half an inch below the level of the former.



## STRUCTURE AND NATURE OF ENLARGEMENT.

On making a longitudinal section through the enlarged right kidney, it was obvious that the pyramids were also enlarged, and that the general structure of the organ was coarser than in the normal kidney. Further, on counting the number of pyramids visible in the section, I found that, notwithstanding the large size of the organ, there were only nine, which is approximately the number visible in a similar section of a normal kidney.

In making comparison with the normal kidney, I counted the number of pyramids visible in a mesial longitudinal section of twenty kidneys obtained from the dissecting room, and found that the average in twelve right kidneys was 9.9, and in eight left kidneys 9.5. Thus in the normal kidneys, though only half the size, there were in the average rather more pyramids visible in the mesial section, than in the enlarged single kidney.

Moreover, on examining sections of the enlarged "single kidney" with the microscope, and comparing these with the normal, the glomeruli and tubules were seen to be much larger than in the normal kidney. The average diameter of twenty-five glomeruli in the "single kidney" was 0.2 mm.; in a normal human kidney used for comparison the average was 0.13 mm. There was a similar enlargement of the tubules of the "single kidney."

Further, on counting the number of glomeruli visible in a given area of the "single kidney," which I accomplished by enumerating those falling within an area of 16 squares ruled on a glass inserted inside the ocular of the microscope, I found that the average number falling within these 16 squares in 50 counts was 2.8 in the "single kidney," 5.5 in the normal. The number of glomeruli falling within the given area, in the "single kidney," thus averages about half that in the normal.

Average number of glomeruli seen  
in 50 counts of 16 squares.

Single kidney.      Normal kidney.

2.8

5.5

$\frac{5.5}{2.8} = \text{approx. } 2.$

The enlargement of the kidney is thus a pure hypertrophy, or enlargement by increase in the size of the constituent elements, and not a hyperplasia, or enlargement by increase in their number. In other words, the total glomeruli in the enlarged "single kidney" must have been approximately equal in number to those contained in a normal kidney, in spite of the great difference in size between the two.



The credit of first pointing out that the enlargement in a case of "single kidney" is a pure hypertrophy is due to Professor A. E. Boycott, who cut serial sections of blocks having a definite weight from kidneys in the rabbit. One of these was taken from a case of single kidney, the others from two "controls." He counted the glomeruli with the aid of camera lucida drawings. My observations on the human subject must therefore be regarded as confirmatory of his work carried out in the rabbit.

#### PRACTICAL CONSIDERATIONS.

The possibility of one kidney being absent has an important bearing on modern surgical practice, and more especially with reference to the operation of nephrectomy.

In considering these cases it is necessary to distinguish between:—

1. Congenital absence of one kidney, including those cases in which one kidney is rudimentary and functionless.
2. Fusion of two kidneys into a single mass (horse-shoe and disc-shaped kidneys).
3. Atrophy or destruction of a kidney as the result of disease.

Secondly, it is of importance to have some idea as to the frequency of these conditions: and thirdly, we must consider the signs and symptoms which would lead one to expect the absence of one kidney, or the fusion of two into a single mass.

The frequency of congenital absence of one kidney, fusion of two kidneys, and atrophic kidneys has been very thoroughly worked out by Sir Henry Morris, who gives the following averages derived from the reports of post-mortem examinations conducted at four London hospitals, combined with published statistics of other writers:—

- |  |                             |
|--|-----------------------------|
| 1. Congenital absence of one kidney              | 1 in 3,992 or .25 per 1000  |
| 2. Fusion of two kidneys (horse-shoe, etc.)      | 19 in 18,244 or 1 per 1000  |
| 3. Atrophied, small, shrunken, or wasted kidneys | 59 in 8,178 or 7.2 per 1000 |

Congenital absence of one kidney is thus seen to be an extremely rare abnormality. From the surgical standpoint, however, in neither of the first two groups should nephrectomy be performed; and probably, in the greater number of cases belonging to the third group, the operation would be contraindicated, as the atrophic kidney, if the other was removed, would be unequal to the strain which would suddenly be thrown upon it. The total number of cases, therefore, falling into one or other of these three groups in which nephrectomy is contraindicated is about 8 per 1000. This number is, however, considerably increased by the fact that when one kidney is absent, or is atrophied, the other kidney is frequently diseased. Thus it is probable that the proportion of cases in which one kidney is

absent would be greater in those subjects suffering from symptoms of renal disease than in the total number of cases examined "post mortem" in a general hospital. Moreover, the importance of recognising the condition is so great, that in all cases in which nephrectomy is contemplated a careful examination should be made to ascertain the existence and condition of the opposite kidney.

The most important signs of absence of one kidney are :—

1. Absence of an ureteral orifice on one side of the bladder.
2. Absence of the "kidney shadow" when the patient is examined with X-rays.
3. Some congenital defect of the external organs of generation on the same side.

In one instructive case described by Guthrie and Wilson, and operated on by W. J. Mayo, absence of the left kidney and ureter was diagnosed by cystoscopic examination previous to an operation for the removal of a tumour, which proved to be the uterus and upper part of the vagina distended with retained menstrual fluid. The lower portion of the vagina, the left ovary and Fallopian tube were completely absent. The labia majora were rudimentary, and the labia minora absent. The case emphasises the importance of cystoscopic examination of the bladder, and also the importance of examining the external genital organs, which, in congenital absence of one kidney, are frequently imperfectly developed on the same side as that on which the kidney is absent.

In the case which I have described, the atrophic condition of the left testicle and deferent duct would, taken in conjunction with absence of the ureteral orifice, have formed a very important clue to the absence of the left kidney.

Abnormalities of the genital organs are, however, not the only congenital defects which may accompany absence of one kidney. In a specimen (558·4) presented by Frank Deas to the Royal College of Surgeons, England, last year, absence of the right kidney was associated with imperforate anus and hydrocephaly. In specimen 702·2, also added to the Museum of the Royal College of Surgeons last year, imperfect differentiation of the sexual organs in a newly born child is combined with an imperforate condition of the rectum. There was also an imperfect penis and scrotum, and no sexual glands.

In my own experience of teratological specimens, I find that one congenital defect is nearly always associated with other defects, and often of some quite distant part. The frequent occurrence in one subject of congenital defects in different and often distant parts of the body

indicates, therefore, that *special* care should be taken to ascertain whether one kidney is absent, in all those cases in which nephrectomy is proposed and some congenital defect, *e.g.* an "accessory auricle" or "club foot," is present.

It is curious that, since writing the above sentence, I have received a letter from Mr Frank Deas, informing me that the child from whom specimen 558·4 was prepared also "had a curious deformity of the hands, which resembled feet." This was not stated in the description in the catalogue.

Absence of the ureteral orifice on one side does not necessarily involve complete absence of the kidney on the same side; it may be present but in a cystic condition, as in a case of Sir J. Bland Sutton's, reported by Sir H. Morris, or it may be otherwise diseased, as in a specimen (648·6) in the Museum of the Royal College of Surgeons, England, presented last year by Dr F. Mott. In this case the termination of the left ureter was congenitally deficient, and the left kidney was saccular and filled with a caseous substance. In these and similar cases, however, the kidney is functionally absent and from the surgical standpoint useless.

Two ureteral orifices may be present and yet one kidney may be absent, or quite rudimentary. The pelvis of the ureter in these cases is also small or absent altogether. The condition, if suspected, might be diagnosed by passing with a catheterising cystoscope an ureteral catheter (which is opaque to X-rays) as far as the renal pelvis. The renal pelvis may then be injected with collargol 10 per cent. in water, and the patient then examined with the X-rays. This should be done on both sides, as the condition is sometimes bilateral. Such a case occurred last year in a female subject in the Anatomy Department of King's College, London. Both kidneys and ureters were atrophied, as were also the ureters, ovaries, and Fallopian tubes. The main blood-vessels of the abdomen and pelvis were also about half their normal size. The method of injecting with collargol would be useful also in the diagnosis of "horse-shoe" and other forms of fused kidney. In these cases the kidney and pelves of the ureters are usually situated near the middle line, and are lower in position than the normal kidney.

Should an operation for nephrectomy have already been commenced, without a previous cystoscopic and X-ray examination having been made, and it is found that the kidney (apart from the disease) is nearly double the normal size, and that there is more than one renal artery and vein, these conditions should lead one to suspect the absence of the opposite kidney, and the operation should not be completed without first having ascertained that the opposite kidney is present.



## ETIOLOGY.

The causation of congenital absence of one kidney and its ureter is, like that of other congenital abnormalities, obscure, but it is probable that the defect originates in an arrest of development of the distal end of the Wolffian duct, and of its union with that part of the cloaca from which the urogenital sinus is derived. The normal outgrowth of the renal diverticulum is therefore checked. The mesonephros, the genital gland, and the upper or proximal end of the Wolffian duct, if formed, subsequently atrophy. This atrophy in the male subject is probably due in part, at least, to there being no outlet for the escape of the testicular secretion.

The frequent cystic condition of the atrophic forms of kidney may be explained by a faulty union, or a complete failure in the union of the tubules of the metanephric blastema with the excretory tubules of the renal diverticulum.

The kidney is congenitally absent on the left side about twice as frequently as on the right. In twenty cases, including my own, the left kidney was absent in fourteen, the right in six. This may possibly be due to the fact that the umbilical cord is most frequently to the right side of the tail in young embryos of from 4-10 mm. length. It is during this period that the Wolffian duct first penetrates the wall of the cloaca and the renal diverticulum grows out from its lower end. Now, as the cloaca will be pulled over to the right with the umbilical cord, it will be farther away from the growing lower end of the Wolffian duct on the left than on the right side. This may account for greater frequency in the failure to unite with the cloaca on the left than on the right side.

## SUMMARY.

In conclusion, I will give a brief summary of the more important points to be learnt from a consideration of these cases.

1. The enlargement of the remaining kidney, when one is congenitally absent, is a pure hypertrophy.

2. The importance of cystoscopic and X-ray examinations, and of noting the presence of other congenital defects, in all cases in which nephrectomy is contemplated.

3. Congenital absence of the kidney and ureter is in all probability due to an arrest in the development of the distal end of the Wolffian duct, and to a failure in its union with the cloaca.

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ON THE PHYSIOLOGY OF THE CRUCIAL LIGAMENTS AND SEMILUNAR CARTILAGES OF THE KNEE-JOINT, WITH A SUGGESTION OF THE ORIGIN OF SOME INSTANCES OF HÆMARTHROS AND LOOSE BODIES. By EDRED M. CORNER, M.C. (Cantab.), *St Thomas's Hospital, London.*

THE exact functions of the crucial ligaments of the knee-joint as given in the text-books of anatomy are abstruse and complicated. Within the last two years, whilst exploring a number of knee-joints surgically, it has occurred to me that the usually given explanation of the functions of these

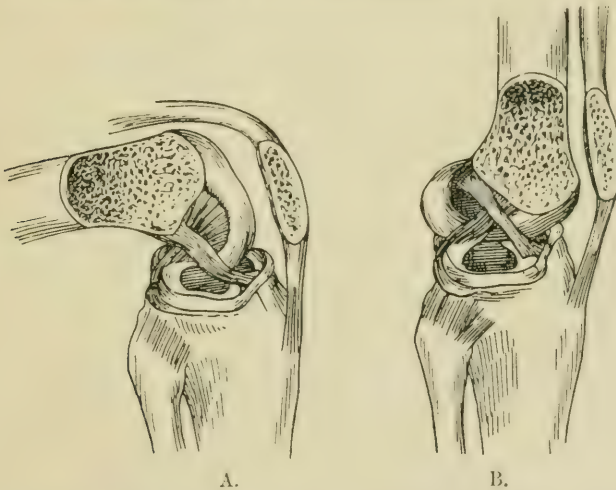


FIG. 1. — After *Quain's Anatomy*, to illustrate the generally accepted physiology of the crucial ligaments. A. The *anterior* tight in extension, slack in flexion. B. The *posterior* tight in flexion, slack in extension.

ligaments is wrong, and that the misleading statements have been copied from book to book, with little or no thought on the part of the authors. Consequently it appeared that there was a useful purpose served in making this brief contribution.

Shortly, the text-book statements which are accepted may be summed up as follows:—

The *anterior crucial ligament* is tight in extension of the knee, and slack in flexion.

The *posterior crucial ligament* is tight in flexion of the knee, and slack in extension.

This is wrong, as can be seen whenever a knee-joint is thoroughly opened and explored, either in the operating theatre or in the dead-house. I had better explain that the joint is best opened for examination by a longitudinal incision over the front of the patella; the ligamentum patellæ, the patella, and the rectus femoris muscle are thus split in the

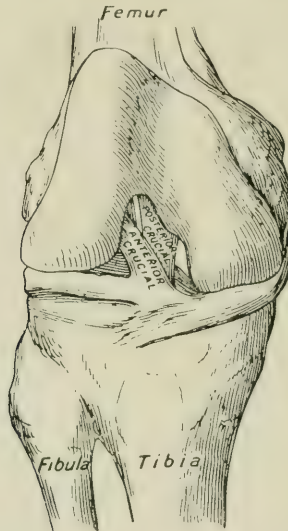


FIG. 2.—After *Gray's Anatomy*, but showing, in spite of the accepted teaching, the anterior crucial ligament tight in flexion of the knee.

same line (see fig. 3, A, B, and C). The two halves of the patella are held aside with hooks, so that by means of flexing the joint full inspection of all parts can be obtained. I had the honour of showing this to the American Medical Association, which met in Atlantic City this year (1914). This is the main source of evidence upon which I base my contentions as to the true physiology of the crucial ligaments of the knee-joint.

The functions of these ligaments are :—

- (1) *Both* are taut in full extension and full flexion.
- (2) *Both* are slack in semiflexion.

The slackness in semiflexion of the knee allows the semilunar cartilages to be injured by rotation movements of the joint in the semiflexed position.

Miners who work in a crouching position, with flexed knees, are well known to be particularly prone to injure their semilunar cartilages. The displaced cartilage is further displaced, permanently displaced, torn, or fractured by any subsequent movement of extension of the joint. Thus we see that the uses of the semilunar cartilages in adapting the joint-surfaces of the femur and tibia are most valuable in positions of semiflexion of the joint, *i.e.* when the crucial ligaments are most slack, particularly in rotation movements of the joint. In fact, it becomes obvious that the crucial ligaments and the semilunar cartilages form part of a mechanism which gives stability to the knee in different positions of the joint. They are interdependent structures, whose liability to injury largely depends on

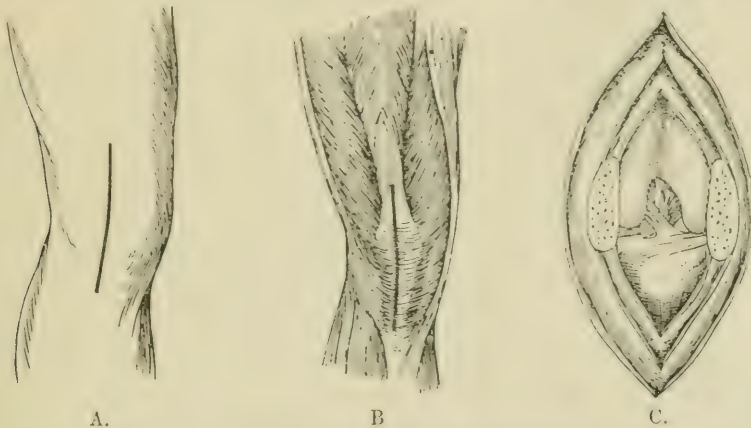


FIG. 3.—Illustrating the method of exploring the joint.

A, the skin incision ; B, the line of division of the rectus, patella, and ligament ;  
C, the joint opened and flexed.

the fact that, though we have assumed an erect attitude with straight knees and taut ligaments, from time to time we crouch with half-bent knees and slack ligaments. Then is the time for injury.

- (3) *Both* ligaments resist rotation movements, particularly the anterior crucial ligament in the external rotation of the tibia. This is well seen in the external rotation of the foot and leg when the crucial ligaments have been destroyed by injury or disease.

The physiology of the crucial ligaments and the semilunar cartilages is exaggerated and perhaps parodied in the injuries of these structures. My knowledge of their physiology was drawn from these sources, and was so definite and decided that I have had the temerity to record my conclusions.

It should be added that the crucial ligaments are likely to play a very



much greater part in the surgery of the knee-joints than they do at present. For instance, this illustration (fig. 4) serves to show how any strain on the lateral ligaments, most frequently internal, is taken up by the crucial ligaments. Their ability to withstand the strain decides whether the complete or partial rupture of the crucial ligaments will occur.

I would note another anatomical fact of great clinical importance. The synovial membrane on the front of the joint, where the amplitude of movement is greater, is more loosely attached to the underlying parts than it is at the posterior parts of the joint, where the amplitude of movement is less. The tight attachment is most noticeable in the reflexion

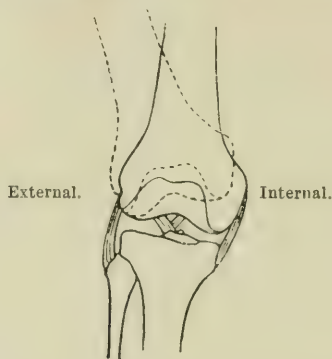


FIG. 4.—Illustrating how the crucial ligaments, in the centre of the joint, take up the strain put on all ligaments on the periphery of the joint.

of the synovial membrane over the crucial ligaments. If reference is made to the last figure (fig. 4) it will be seen that the strain of practically all injuries to the joint is taken up by the crucial ligaments. In consequence the ligaments, particularly the anterior, I believe, are often stretched. These ligaments are an arm of fibrous tissue in a sleeve of tightly applied synovial membrane. Were the stretching capabilities of fibrous tissue and synovial membrane the same, all would be well. But they are different, and with the more severe strains the synovial membrane splits. From these ruptures comes the blood so commonly found in effusions into the knee consequent on an injury. Further, in the healing of these lacerations layers of fibrin may be detached by movements of the joint. Many such detached fibrinous bodies will be removed by leucocytes. A few will remain behind to form the nucleus of loose bodies in the joint. Their subsequent trituration in the joint, produced by the movements, leads to

changes in them which completely obscure their origin. For years loose bodies may give rise to few or no symptoms. Then they get nipped in between the femur and the tibia, perhaps broken. After this they may settle and become attached to the synovial membrane. Their attachment to the synovial membrane is a reversal of the ordinarily accepted doctrine that some of these bodies arise by becoming detached from fringes of the synovial membrane.

THE EPIPHYSIS OF THE HEAD OF THE FEMUR. By THOMAS  
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So far as the writer is aware, there is on record no detailed description of the epiphysis of the head of the femur—that separate centre of ossification in the continuity of the cartilaginous “Anlage”—apart from the usual statement that the margin of the articular cartilage of the head represents the position of the epiphyseal cartilage.

At birth, as is well known, the femur is ossifying in its diaphyseal portion, the lower epiphyseal centre is usually present, but the whole of the upper extremity of the femur is as yet one undivided mass of cartilage—the tri-epiphyseal cartilage (fig. 1). In this upper cartilage appear

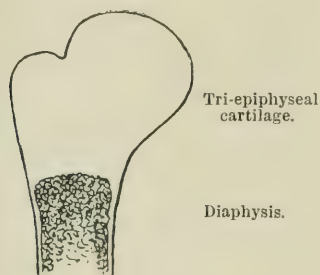


FIG. 1.—The proximal extremity of the femur, at birth.

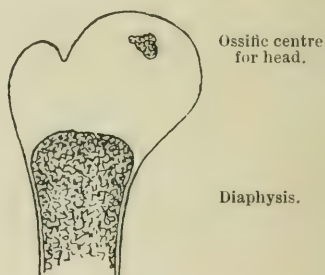


FIG. 2.—The ossific centre for the epiphysis of the head, at eleven months.

ossific centres, for the head towards the end of the first year, and subsequently for the trochanters. In the consideration of that centre which ossifies as the articular portion of the head of the femur, there will fall for study the shape and change of shape of the epiphysis, the position and change of position of the epiphyseal cartilage, the effects of these changes in addition to their causation, and of this especial epiphysis its blood supply.

The ossific centre for the head, often surrounded by a number of small osseous granules, appears then a little earlier or a little later towards the end of the first year,<sup>1</sup> and the position of its earliest occurrence is above and medial to the centre point of the whole head (fig. 2). After the

<sup>1</sup> This centre may appear at the tenth month, or may be absent at the thirteenth month.

appearance of this ossific centre, the head, yet mainly cartilaginous, is still connected with the great trochanter by a thick mass of epiphyseal cartilage: but after differentiation of the trochanter as a separate ossification, these two epiphyses are gradually separated from one another by the growing diaphyseal neck, and subsequently increase in size quite independently of one another. By the end of the fourth year nearly the whole of the epiphysis of the head is osseous, the cartilage now consisting only of the thin dentate epiphyseal cartilage separating the head from the neck. At seventeen years the epiphysis is fully ossified, and finally joins the diaphysis about nineteen to twenty years, though a line of separation often persists at the circumference, especially at the lower part, even with

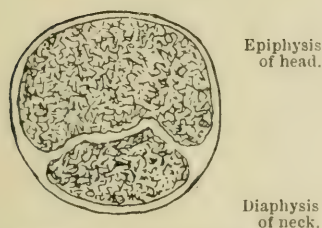


FIG. 3.—Section through head of femur, medial and parallel to the articular margin, at twelve years.

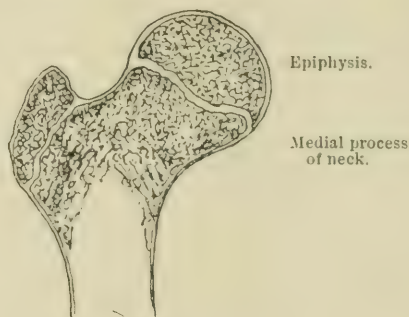


FIG. 4.—Vertical section of femur, at twelve years.

firm osseous union at the centre. On section, a line of dense bone persists for some years, indicating the line of cartilaginous union. Taking, however, a section through the head parallel to the articular margin but medially distant about one centimetre, such as is represented in fig. 3, at about twelve years of age, there is clearly shown the large part taken by the diaphyseal neck in the formation of the central core of the head, and the peculiarity of the manner in which it does so. This peculiarity consists of the greater proportional representation of the diaphysis at the under part of the head as compared with the upper. An examination of the upper surface of the diaphysis is explanatory of this peculiarity, for on reference to fig. 4 it is clearly shown that the inner end of the neck projects above the general plane of the rest of this diaphyseal surface. At this age (twelve years) the diaphysis of the neck forms a central core down over which the articular surface of the epiphyseal head extends: not in a regular fashion, however, but yet so as to embrace the upper end of



the neck in a circularly complete manner. While the under surface of the epiphysis of the head is thus concave in all directions, it is most deeply excavated at its application to the medial process of the neck, and the extension of the epiphysis over the diaphysis is in this situation the most limited. (Macalister has already pointed out how the thin irregular rim from the head extends outwards over the upper part of the neck, and assists in the transmission of weight from the head above to the calcar femorale of the neck below.) From a morphological point of view, however, it is more important to recognise that the lower aspect of the epiphyseal rim extends to the least extent over the diaphyseal neck, that it is the thinnest part of the whole epiphysis, and that it is the last portion to become osseous. It will also be noted, and more especially at the period immediately previous to the bony union of the epiphysis with the diaphysis,

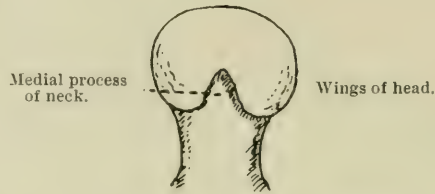


FIG. 5.—Head of femur of seal—diagrammatic.

that both ossifying surfaces are irregular; and the irregularities are so arranged and of such a shape, that small hemispherical nodosities of the upper surface of the neck are occupying small concavities of the under surface of the head.

On tracing the ontogeny of this epiphysis, the diaphyseal spur at the medial extremity of the neck will be found to be best developed towards the age of puberty; and though in the process of formation it may be recognised at an earlier period of life, till the age of four years it is certainly non-existent. The advantage gained by such a process is in preventing any undue tendency to luxation of the epiphysis, a tendency, as may be shown, at its greatest degree of mechanical possibility when this natural means of prevention arrives at its maximum of development. A comparison with the femur of the seal is instructive not only as regards the phylogeny of the medial process of the neck, but also in assisting to a decision of the morphology of the ligamentum teres of the hip-joint. In the Ross seal the articular head of the femur is incomplete, so that the medial process of the neck is entirely a superficial structure (1) (fig. 5). That the ligamentum teres is isolated by the development of the head of the femur as a wing expansion on each side of the ligament, with subsequent

fusion of the wings under the ligament at the lower part of the head, as stated by Keith, seems strongly substantiated by the mode of development of the epiphysis.

The axis of the head and neck of the femur in the foetus is, in respect to that of the shaft, vertical, or perhaps spiral, so that the angles of inclination and declination are both of large size (150° and 45° respectively), and till the end of the first year there is little alteration of the femur in these respects. The epiphyseal cartilage will thus be found horizontal in position even as late as the third year. After this period, however, the cartilage comes more and more to occupy an oblique position, so that before its final absorption it slopes downwards and inwards at an angle of at least 30°. As causative of this change there is the interaction of the developmental and mechanical forces. For, on to the almost vertically growing femoral neck of the young subject there is transmitted, more on its medial than on its lateral side, a shearing force acting vertically, tending to produce an angle between the two components of the femur, and as a result there is, not a bending of the cartilaginous tissue of the head or of the osseous tissue of the neck, but a change in the plane of the epiphyseal cartilage. This cartilage is horizontal in the young bone, and to assume the adult obliquity there is, as it were, a greater amount of growth at its outer end than at its inner end. As a direct result of this change in position there are two alterations in the form of the femur. Firstly there is the progressive decrease in the angle of inclination of the neck, and secondly there is the alteration in position of the axis of the head. The head, transmitting the same vertical force as before, becomes "tilted over" to the oblique adult position, so that at that period of life, ten to fourteen years, while the cartilage is in the adult obliquity yet still cartilaginous, there is the greatest tendency to the occurrence of the condition of "traumatic slipped epiphysis."

The blood-vessels which enter the hip-joint by passing under the transverse ligament of the acetabulum have been defined by all observers as arising from the external branch of the *a. obturator* and from the medial circumflex branch of the *a. profunda femoris*. The work of Ssawwin (2) is the most detailed. He demonstrated by means of very fluid injections that the obturator branch anastomosed with that of the medial circumflex to form two main vessels, one, the *a. acetabuli*, constant, which formed a rich vascular network in the Haversian fat, the other not at all constant, the *a. ligamenti teretis*, which ran through the ligamentum teres to the head of the femur. In some cases he found no vessel in the round ligament at all, in most a fairly well-marked channel, and in a few specimens a double artery.

The method adopted by the writer was one of differential injection with very fluid media, the posterior division of the internal iliac artery being injected with one colouring matter, and the rest of the body with a differently coloured preparation. By this means it was determined that running underneath the transverse acetabular ligament there is a large branch from the external division of the a. obturator, and a smaller branch from the internal circumflex artery. These two vessels united in the floor of the acetabulum and formed a network, exactly as described by Ssawwin, and from this network a small branch proceeded to the ligamentum teres.

Many authors hold, of course, that this is the sole function of the ligamentum teres, to lead vessels to the head of the femur.<sup>1</sup> After a most careful inquiry Welcher (3) came to opposite conclusions. On an analysis of 30 cases he found that

- in 9, there were no vascular markings on the floor of the teres fossa ;
- in 11, only one or two small pits ;
- in 8, there were three to six foramina :
- in 1 ten, and in 1 twenty-five small openings.

Hyrthl also upholds the view that the ligament does not convey blood-vessels to the head of the femur, and claims to have proved that at the femoral extremity of the ligament the arterial vessel forms a capillary loop and runs back as the vein. For the present work about 100 round ligaments were examined for the contained vessel by means of a hand lens, yet a vessel of any size was never found ; therefore it was concluded that not only is this vessel not the sole supply, but that it can convey only a very trifling amount of blood to the head of the bone. On minute examination of the "differentiated" specimen numerous vessels were found ascending to the head from the articular margin, but not the slightest evidence of any vascular channel from the ligamentum teres into the neighbouring bone could be determined : that is, in the adult at least, the blood-vessels of the ligament are not destined for the supply of the head of the femur. In support of this anatomical fact there is the finding of pathology, first in regard to dislocation of the hip, and secondly in fracture of the neck of the femur. For the full development of the former condition there must be of necessity a complete rupture of the round ligament, yet after reduction of the dislocation it is never held that the head of the femur is defective in nutrition. A considerable amount of detailed work is available in regard to fracture of the neck of the femur, and here the consensus of reliable opinion is that the condition of the ligament is absolutely immaterial, the rupture or non-rupture of the synovial and

<sup>1</sup> Henle and Sappy both held this view.



fibrous connexions between the neck and the head with the contained vessels determining the future state of the head.

It is in the child, however, it is by some writers held, that the ligamentum teres as a means of leading vessels to the femoral head is in the fullest degree active, and after that period the blood supply is derived from the blood-vessels of the diaphysis at the articular margin (Lange). Against this view there are the very dogmatic statements of Fick and of Welcher. The former (4) definitely states: "In the young subject the blood supply is not through the round ligament, but through the vessels which enter the large foramina at the articular margin of the head": while the latter is equally certain of this view in the determined absence of vascular foramina in the teres fossa of the embryo and of young children.

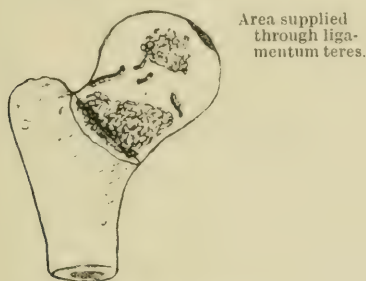


FIG. 6.—Blood supply of centre of ossification, at two years of age.

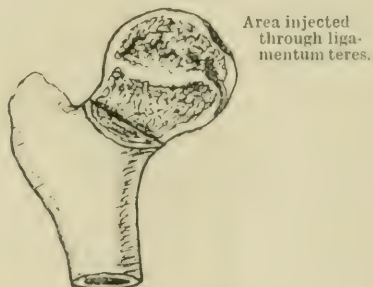


FIG. 7.—Blood-vessels of head, at six years of age.

For the present work two male children, aged two years and six years respectively, were prepared by the differential injection method already described. In the child of two years—that is, at a period when the ossification of the head is not to any extent advanced—the blood-vessels which passed to the osseous nucleus were derived in no part from those of the ligamentum teres, but entirely from vessels entering the neck of the femur at the articular margin of the head. These vessels are distinctly seen in their course to the centre of ossification, lying in the lower part of the cartilage of the head, but a small area of the superficial cartilage above this centre and in the immediate proximity of the attachment of the ligamentum teres did seem to be vascularised from the a. ligamentum teretis (fig. 6). The specimen obtained from the child of six years (fig. 7) also gave emphatic evidence that for purposes of ossification the blood supply is obtained, not from the vessels of the ligamentum teres, but from those which enter at the articular margin of the head and pass thence proximal to the epiphyseal plate to ramify in the osseous substance of the



head. And when in addition it is determined in those cases of congenital dislocation of the hip that the head of the femur undergoes no especial atrophy in the absence of the ligamentum teres, it may no longer be held that "the round ligament conveys a blood supply to the head of the femur."

As regards the foramina in the floor of the teres fossa, the following alternative view as to their causation is advanced. From a detailed examination of these foramina there is made evident not only the inconstancy in number as described by Welcher, but that the sectional area of the average number is out of all proportion to that which could possibly result from a subdivision of the a. ligamenti teretis: that is, all of these openings could not possibly be intended as vascular channels. Now, from a study of the method of attachment of the ligamentum teres to the head of the femur in the fœtus and in the adult, it may be shown that, while the marginal parts of this ligament may become continuous with the superficial layers of the articular cartilage, the central parts are in direct continuity first with the cartilaginous and subsequently with the osseous substance of the head. And the foramina, found only in the adult, represent such channels of communication.

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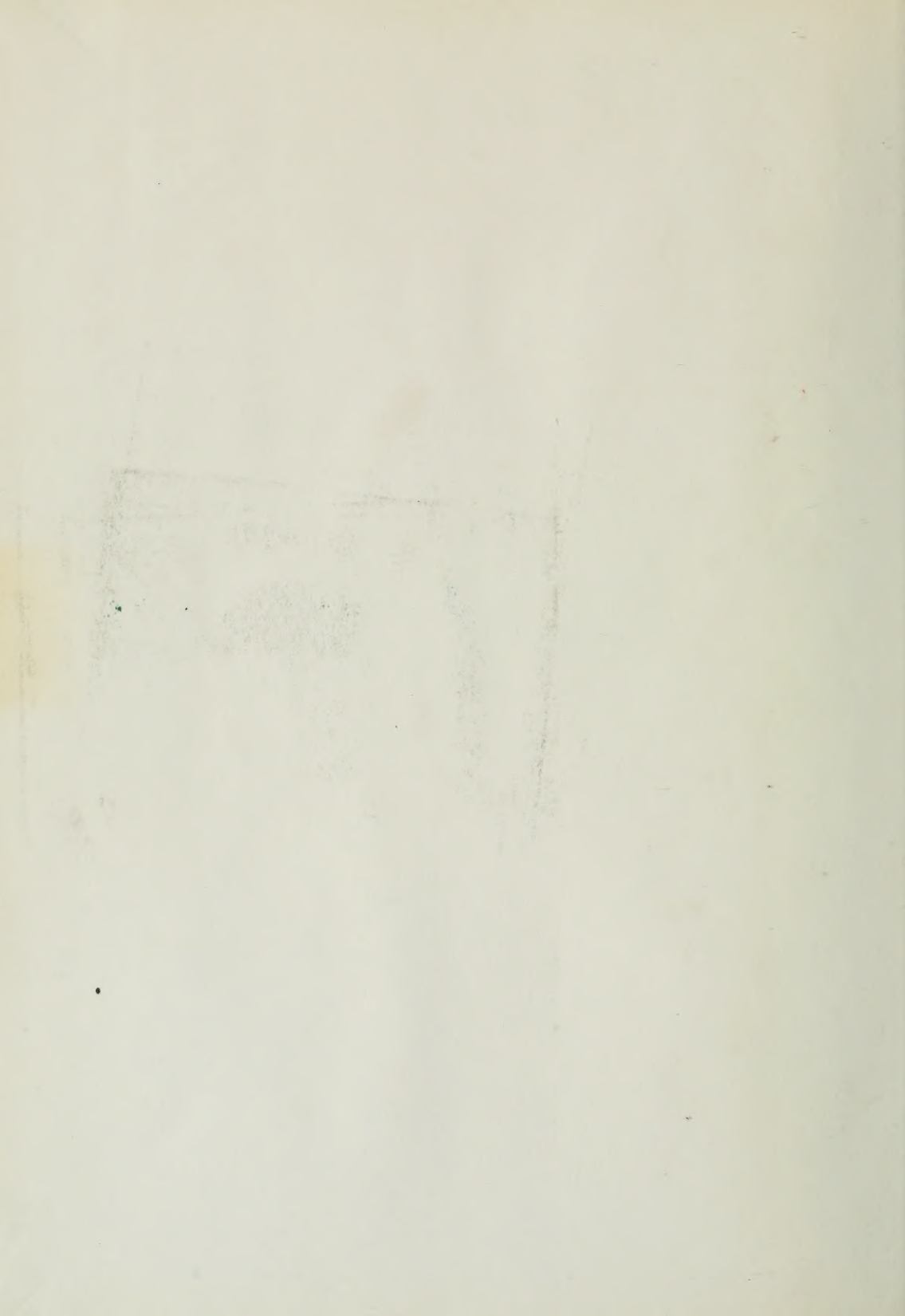
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